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EXPLOSIONS IN COAL MINES.

INTRODUCTION.

The writers propose to consider the subject of explosions in coal mines from the basis of experience gained by direct investigation. Six explosions will be particularly described, and reference will be made to others.

The six explosions may be classified thus :—

Date of Explosion.	Name of Colliery.	County.	Lives lost.	Time of Explosion.	Seams of coal affected.
1880. 8 Sept.	Seaham	Durham ...	164	2·20 a.m.	Maudlin & Hutton Seams.
1882. 16 Feb.	Trimdon Grange	Durham ...	74	2·30 p.m.	Harvey Seam.
18 April	Tudhoe	Durham ...	37	1·15 a.m.	Brockwell Seam.
19 April	West Stanley ...	Durham ...	13	1·0 a.m.	Busty Seam.
25 April	Whitehaven ...	Cumberland	4	11·15 p.m.	Main Band.
1885. 2 March	Usworth	Durham ...	42	8·58 p.m.	Maudlin Seam.

All these explosions were confined in their effects, so far as loss of life, and practically so far as force exhibited and burning were concerned, to one plane or set of workings. In all the cases there were workings on other planes or levels, connected by vertical approaches only, with the planes of explosion, which were not affected; that is, the explosions only extended in a more or less horizontal direction; in no case ascending or descending vertically so as to continue the explosion on another plane. This statement is made in order to explain the omission of plans showing the unaffected portions of the mines. The fact of the explosions not ascending or descending vertically has, however, a significance which will be referred to later.

In the Seaham explosion all the main haulage roads for some distance from and on both sides of the downcast shaft were affected. At Whitehaven the explosion did not affect the shafts. In the other cases the explosions extended to and damaged the downcast shafts, but did not cross them so as to extend itself on the opposite side: some little damage observed across the shafts in these cases was caused by the explosion on the other side. This statement is made to explain the omission on the plans of the workings, on the same level across the shafts, into which the explosions did not extend. This fact has also a significance to which further reference will be made.

The following is a general description of the mode of working large collieries, such as those under consideration.

The shafts, always two in number, and sometimes more, are usually sunk in close proximity. This is done in order to have the whole surface establishment compact, and to enable the system of ventilation to be completed as soon as possible. The completion of the ventilating system is effected by connecting the shafts in the seams or beds to be worked by passages driven in the coal. A seam or bed of coal, having two shafts connecting it with the surface, and these shafts being connected underground, the conditions necessary, so far as shafts are concerned, are complete.

The working of the coal may be carried out by two methods: the "board and pillar" or the "longwall." The board and pillar system of working coal is to form, in the first instance, pillars or blocks of coal of the size shown on the plans, and in a second working to remove these pillars in slices. The passages completed in the first or "whole" working, as it is termed, are called "boards" and "walls." The coal is, as a rule, more easily detached by the hewer when working at right angles to the cleavage, and advantage is taken of this to work in the first or whole working most of the coal out of passages driven at right angles to the cleavage, and called boards; these passages are usually 5 yards wide. The walls are places driven at right angles to the boards and parallel to or with the cleavage, and are more for the purposes of ventilation and carriage of the coal than as a source of mineral; they are usually driven 2 or 3 yards wide. In many deep pits, and in some of those under notice, the cleavage is so little defined, that all the passages in the first working are driven the same width, viz., from 3 to 5 yards.

The first or whole working is succeeded by the second or "broken" working, which removes the pillars and leaves a part of the mine called "goaf," from which all the coal is taken. Sometimes the second or broken working is prosecuted behind an advancing face of whole working; this is called "following the whole with the broken;" leaving pillars of coal next the main intake and haulage road to protect it and the necessary return air ways. The broken working having followed the whole to the extremity of the royalty, the last operation is to remove the pillars left on each side of the haulage road.

The longwall method of working coal is to remove the seam in one working only, the roadways being carried through the goaf or space from which all coal has been abstracted.

Certain modes of working coal are modifications of these two general systems. Thus the roadways are sometimes protected by pillars of coal; longwall being prosecuted on each side of such protected roads either away from the shafts, or, as in the Lancashire system, where the practice is to form by pillar workings, roadways to the extremity of the royalty, and then work longwall home or back to the shafts. At the collieries under notice, the board and pillar system was in operation, with the exception of a small district of longwall at Seaham colliery, and a modification of longwall in one district of Trimdon Grange colliery. The mode of working does not appear to have had any direct bearing on the causes of the explosions.

Each hewer can detach and fill into tubs from 3 to 5 tons of coal per day, and in order to obtain a sufficient quantity of coal, many working places have to be provided. In the whole or first working, each man is placed from 10 to 40 yards apart, and in the broken or second working, from 5 to 20 yards. This necessitates long lines of working face. The carriage of the coal from the working face is performed by ponies in the first instance, drawing a single tub, then by horses taking several tubs, and finally by engine power, or if the road inclines sufficiently to the shaft, by self-acting inclines. It is found convenient and economical to limit the distance travelled by ponies drawing single tubs to about 150 yards, and in order to do this it is necessary to have, at suitable distances apart, main roads traversed by horse or engine power.

The general direction of the main roads of a colliery are influenced by the inclination of the seam, shape of royalty, and presence of large dislocations.

The ventilation of the mine requires that each district shall have two roads connecting it with the shafts, so as to allow a current of air to pass; this current is induced by a furnace at the bottom of the upcast shaft, or by a fan on the surface.

The foregoing general description of the internal economy of a coal mine is sufficient for the purposes of this paper, but will require amplification in some respects.

It will be seen that the mine can be divided into the following sections :—

- Shafts.
- Roadways.
- Working faces.
- Abandoned parts (goaf and pillars awaiting removal).

Shafts are maintained for the following purposes :—

- Fresh air entering the mine, and return air leaving the mine.
- Drawing minerals by winding engines.
- Passage of men and materials.
- Pumping and drawing water, and transmission of power.

Roadways are maintained for the following similar purposes :—

- Ventilating the mine.
  - Intake air ways.
  - Return air ways.
  - Face ventilation.
- Haulage of mineral.
  - Roads traversed by ponies.
  - Roads traversed by horses.
  - Roads traversed by engine power.
  - Roads forming self-acting inclines.
- Passage of men and materials.
- Water roads and roads used for the transmission of power.

Plans No. 1 show the workings and ventilation of the parts of the collieries affected by the explosions. The roads traversed by the fresh or intake air currents are coloured blue, and these were, with some few exceptions, also the main haulage and travelling roads.

The working faces are shown by thick black lines.

The return air roads are coloured red.

Pillars formed and awaiting removal are shown by thin black lines.

The intakes, where used also as haulage and travelling roads, are usually from 6 ft. to 9 ft. wide and from 5 ft. to 7 ft. high; where only used as intakes, or intakes and travelling roads for men and horses, the size is usually somewhat smaller.

These roads are, where necessary, made of sufficient height by taking away part of the roof stone or floor of the seam. They are made of a suitable gradient for haulage, and at many points leave the coal altogether, as when crossing dislocations, or where the coal sinks into a trough and rises again. They are securely timbered, and in places where the roof stone is especially bad, arched with bricks. They are kept up to within as short a distance of the face as possible. The coal is hauled over the greater parts of these roads by engine power.

The air current is carried forward by "stoppings" or doors placed in all the side openings. The stoppings, with the exception of those near the face, are of brick or stone and are built with mortar; they are frequently stowed with loose stones behind the mason work or on the return side. The stoppings near the face are constructed of wood or canvas; the wood stoppings are sometimes pointed with mortar at the joints. At points where it is necessary for men and horses to pass from the intake, doors are provided, usually of wood, and in the case of important doors, which if left open would deflect the air current from large areas of workings, they are in duplicate, and near the shafts even trebled. At points where men only pass from the intake into the return, smaller wooden doors, called man-doors, usually kept locked, are provided. Double doors are provided not only to double the security when not in use, but also to admit the passage of men and horses past them without air, one only being opened at once. They are in fact air locks.

In less important situations one wood door and a sheet of canvas are used, sometimes one wood door only or two canvas sheets are provided, and at points of least importance one canvas door only is hung.

It will be seen that the principle adopted in the ventilation is to carry forward the air along single roads with as little leakage as possible, the vigilance being somewhat relaxed as the face is neared and less resistance has to be overcome by the air current before reaching the working places.

The air current before reaching the workings is closely confined, because, after reaching the bottom of the downcast shaft, it always has a tendency to take the easiest route to the bottom of the upcast shaft, and the object of stoppings and doors is to make the only route, by the face.

It has been found advantageous to divide the current of air: by allowing separate currents from the main air current to traverse the branch roads the friction of each current is lessened and a larger quantity of air is obtained in the aggregate. The friction of the air against the sides of the roads is the principal resistance to be overcome by the ventilating power; the force necessary to give motion to the air being small compared with that necessary to overcome the friction. The friction of air against the sides of the passages varies as the square of the velocity of the air; by splitting the air current the velocity is reduced and the friction lessened by a greater ratio, and the same ventilating power is enabled to circulate a larger volume than if the air had been confined to one passage only.

The various currents of air are called "splits." When the air is split it is often necessary to have two currents of air crossing each other, and air crossings are provided for this purpose. When the return air passes above the intake, the crossing is sometimes called an "overcast;" when the return air passes under the intake it is sometimes called an "undercast." These crossings are usually made by building a brick arch in the intake, closing the upper ends of the arch, and making above it a road for the return air. Sometimes a wooden bridge closed at the sides is used. In some instances the crossing of the air currents takes place at points where the intake and haulage road has left the seam of coal and is separated from it by some thickness of rock, the return air road being in the seam above or below the intake. Such crossings may be called natural crossings.

In splitting the air into two or more currents, the resistance to be overcome by each being often unequal, or more air being required in one current than in others, artificial resistance is resorted to in the shape of "regulators," so as to secure to each split the required quantity of air. These regulators, usually sliding doors partly open, are places where the flow of air is checked by a contraction of the air way. They are placed in the returns out of ordinary workmen's reach, but can be opened so as to permit the passage of a man. Regulators may be a brick taken out of a stopping, a hole in a brattice stopping or in a door, or simply leakage through doors. When the current is allowed to deflect from an intake through a regulator it is usually called a "scale" of air.

The air current, having reached the face, is conducted past the various working places; and into the face of them when necessary, by means of canvas or wood brattice. Sometimes brick brattice or air boxes or tubes are used. After leaving the working places it passes into the return air way.

The return air ways are separated on one side from the intakes by the stoppings and doors already described; on the other side they are not so protected, but are open to the goaf and pillars. The air, having left the last working place, is no longer rigorously confined to one road, but is allowed to pass to the upcast shaft along the return air roads and through such places in the pillars as may be open. One or more roads for the passage of the return air from each district is always kept open and travelled frequently. The roof of these roads is supported by stone pillaring and timber; pillars of stone are preferred in return air roads; the stone is usually available from the falls of roof that take place, and timber is not always at hand at points in the return distant from doors.

Timber also is more subject to rot in the return air ways than in the intake. The return air roads are, on the average, smaller than the intake air ways; in the case of main returns they are, however, often larger than the intake.

For convenience of access and examination, and for removal of fallen stones when necessary, the return air ways are, as far as possible, maintained next to the intake air ways, being separated from them by one pillar of coal with the stoppings and doors already described.

Requirements connected with the system of working make it generally necessary to have the return air ways parallel to and near the intakes. The air always has a tendency to pass from the intake into the return and not from the return into the intake.

It is usual in some cases to ventilate one district by a current of fresh air and then conduct this air to another district and ventilate it by the same air. This is called ventilating "by return air;" that is, the air, after leaving the first district, is return air so far as it is concerned, but is intake air so far as the second district is concerned. It is usual in such cases to allow a scale of fresh air to pass through the doors on the haulage road of the second district and join at the face the return air from the first district.

In mines subject to fire-damp it is an almost invariable rule not to use the return air roads for the haulage of coal, and this principle was observed at all the collieries under notice.

Fire-damp or light carburetted hydrogen existed in the coal and stone at all the collieries under notice, and issued constantly from the freshly exposed surfaces in the working places; the ventilation, however, was such that gas was not frequently seen on the lamp in the working places or return air roads. It was quite expected that, after the ventilating current had reached the working face, and from thence to the upcast shaft by the return air roads, gas might be seen at any time, and these parts of the collieries were worked exclusively with locked safety lamps.

Gunpowder was used in working the coal in parts of the Trimdon, Tudhoe, and West Stanley Collieries, the shots being fired by officials after an examination of the place and its surroundings as regards gas.

It was not considered probable that any gas would be seen on the main haulage roads traversed by large volumes of fresh air, their surfaces having long exhausted themselves of gas. The best test as to the feeling of security on these roads is to consider the position of the "caution boards." These are points on the intake where workmen's safety lamps are examined, locked, and re-lighted when necessary. They are shown by a red C on Plan 1.

The practice as to the use of safety lamps and open lights varied to some extent at the different collieries.

At Seaham, Trimdon Grange, Tudhoe, and West Stanley Collieries open lights were used on the intake air ways up to the caution boards, which, in several instances, were more than a mile from the shafts. Repairers and stonemen, whose work lay on either side of the caution boards, used safety lamps, even when working on the out-bye side of the caution boards.

At Whitehaven Colliery only safety lamps were used in the district of the explosion.

At Usworth Colliery the use of safety lamps was enforced, except in the immediate neighbourhood of the downcast shaft. Workmen's lamps were examined and re-lighted when necessary at the points marked C on Plan 1.

At some collieries, where the issue of fire-damp is of very limited quantity, it is the custom to use naked lights on the haulage roads and in the whole or first workings, safety lamps being used in the broken or second workings and in all the return air roads.

"Blowers" or sudden issues of fire-damp were sometimes met with in the first or whole working, the gas on a few occasions coming off in sufficient quantity to show on the safety lamp over a district, and in the return air ways heading from it; under such circumstances work was suspended until the gas cleared away. In the broken or second working the ventilation is more difficult, and gas was frequently seen near the edge of the goaf. After a slice of coal has been removed from a pillar of coal, the timber put in to support the stone is withdrawn, and heavy falls of roof occur, exposing new surfaces above the level of the seam; gas issues from the newly exposed surfaces, and being lighter than air, remains in the cavities formed, and is difficult to remove.

The gas issuing both in the first and second workings is carried by the ventilating current into the return air ways, and the writers know of no case where gas issuing from the working faces has shown any considerable distance *against* the air current.

The goaf of a coal mine is sometimes looked upon as a reservoir of gas, and in inquiries into the cause of explosions, loose statements as to gas issuing from goaves are very common. The writers believe that in all the six cases under consideration, gas contained in the goaf did not play any part in the explosions; all the indications of direction of force and flame showing that the explosions had travelled towards the various goaves and not in a single instance from them. The goaf is not open, except at the edge next the face of the second or broken working, where new falls are constantly taking place, and gas issues after such falls; so far in the goaf would be found to be almost close and the exposed surfaces exhausted of gas. In the longwall system of working, the main roads are carried through the goaf, and it is found to become comparatively close away from these supported roads in a short space of time. That gas issues from goaves and sometimes in large volume is admitted, the gas passing into the returns. The distance for which goaves remain more or less open, and the time necessary for them to consolidate, depend chiefly upon the nature of the roof and floor.

The return air of the collieries under notice rarely showed any indication of gas near the upcast shaft. In one or two instances gas was so seen.

It is necessary to explain how far the flame of a safety lamp may be taken as an indicator of fire-damp.

Mr. Galloway, in the Transactions of the Royal Society, Vol. XXIV., gives the result of experiments made by him to test "the accuracy of the means by which the presence of fire-damp is usually ascertained in mines."

A Clanny lamp, or lamp with glass surrounding the flame, was used, and the wick carefully trimmed and pulled down "until the flame presented the appearance of a small blue hemisphere about $\frac{1}{8}$ in. high by $\frac{1}{4}$ in. diameter at the base, and having a conical speck of yellow in the middle near the top;" this flame was then exposed in mixtures of fire-damp and air, the proportion of each being known.

He gives the following table:—

1	Vol. Fire-damp to	14	Vols. Air	...	Slightly explosive.
1	,, ,,	15	,,	...	Inflammable.
1	,, ,,	16	,,	...	Gave a voluminous, waving, spindle-shaped, pale blue cap, $3\frac{7}{8}$ in. high.
1	,, ,,	18	,,	...	A similar cap, 2 in. high, which burned rather more steadily.
1	,, ,,	20	,,	...	A cap, $1\frac{5}{16}$ in. high, cap perfectly steady and more distinct than any of the others.
1	,, ,,	25	,,	...	A conical cap, $\frac{1}{2}$ in. to $\frac{5}{8}$ in. high.
1	,, ,,	30	,,	...	A conical cap, $\frac{3}{8}$ in. high.
1	,, ,,	40	,,	...	A conical cap, $\frac{3}{16}$ in. to $\frac{1}{4}$ in. high.
1	,, ,,	50	,,	...	An exceedingly faint cap, $\frac{1}{8}$ in. high, the top having the appearance of being broken off.
1	,, ,,	60	,,	...	It was hardly possible to distinguish anything above the small oil flame.

It will be seen that the miner speaks of air containing no visible appearance of gas when there is less than 2 per cent. of it in air. The return air of all the collieries under notice, as a general rule, contained less than 2 per cent., the actual amount of fire-damp normally issuing from the mines may, therefore, be put down as less than 2 per cent. of the air current entering the upcast shaft.

The fire-damp actually contained in the return air at the upcast shaft is practically what enters it while passing the working faces, and while skirting goaves, and passing through the old pillars in the return air ways. It is assumed that the air is free from fire-damp on the main haulage roads. This may not be absolutely true, traces of it may be present in the air on such roads, but in minute proportions.

A rough calculation may be made as to the probable percentage of gas in the air on such roads in this way.

Assuming that there is 2 per cent. of fire-damp in the return air at the upcast shaft, we might fairly say that half of this fire-damp entered the air current at the working face, the remaining half, or 1 per cent., must be divided between the intake and return air ways; the return air ways are open to and connected with the goaves and old pillars, while the intake is a single road with the pressure of air from it on both sides; if, therefore, we say that the air while in the return picks up $\frac{4}{5}$ of the remaining 1 per cent., it might, in the writers' judgment, be an approximately fair division. The intake air on reaching the first working place would, by this estimation, contain $\frac{1}{5}$ per cent. of fire-damp, most of this would enter the air near the end of the intake, and where the coal and stone had not had so long a time to drain of gas, thus in an intake air way one mile long, it would be fair to assume that $\frac{2}{3}$ of the $\frac{1}{5}$ per cent. of fire-damp would enter the air in the last half mile, leaving $\frac{1}{3}$ of $\frac{1}{5}$ or $\frac{1}{15}$ per cent. of gas present in the air at the end of the first half mile, or 1 volume in 1500.

It cannot be doubted that even in fiery mines the air before it has passed over any working places is nearly free from fire-damp. If 2 per cent. of gas entered the air current in those roads where the issue of fire-damp has practically ceased, the return air at the upcast shaft would contain at least 10 per cent., and be in a constantly explosive condition; a state of things negatived by observations extending over many years.

Blowers or sudden outbursts of gas were never met with on the main intake or haulage roads, except when these roads formed part of the working face. In a few cases in the North of England, an issue of gas has been met with on a main road when first driven, and the issue has not at once exhausted itself, but has continued coming off for years, generally decreasing in volume and often varying with the barometer.

At none of the collieries under notice was there any such permanent issue of gas on the main roads.

The writers know of no example of a blower of gas appearing on a main road after it has been formed for some years. Falls of stone occasionally took place on the main roads of the collieries under notice, but in no case was a large volume of gas suddenly liberated by such falls. Cases are known on old roads where gas has collected in the cavity formed by a fall of stone. The gas in these cases was not observed to have come off as a sudden outburst, but to have accumulated in the cavity in the roof where it was out of the direct current of the air.

The only agent, other than fire-damp, ever suggested in connection with explosions in coal mines as capable, when mixed with air, of causing these calamities, is coal dust, either alone or in conjunction with fire-damp.

It was found that the parts of the Seaham, Trimdon Grange, Tudhoe, West Stanley, and Usworth Collieries affected by the explosions were those in which coal dust was present in considerable quantities. The locality where the Whitehaven explosion occurred was quite free from coal dust, the surroundings being all damp or wet. This was a pure fire-damp explosion, and the most extensive of its kind that has come under the writers' notice.

There are two conditions necessary before coal dust can accumulate in mines, the first is that the mine must be a dry mine, and the second is that the coal must be of a dusty nature.

The dryness of the air in a mine depends upon the temperature of the mine and its freedom from water. The temperature of the earth's crust increases with its depth; at 50 feet from the surface the temperature is 50 degs. F., and below that depth the temperature rises 1 deg. for every 60 feet. Deep mines are therefore warmer than shallow mines.

Virgin coal and rock, even at great depths, is often charged with moisture. When this is the case, and gas issues freely from the strata, a hissing noise is heard, called "singing," and when the moisture is so abundant as to form drops of water on the newly-exposed surfaces it is called "bleeding." After a time the singing and bleeding cease, and the coal becomes dry. Sometimes the coal and surrounding strata are dry when first exposed, so far as can be observed, and then no singing is heard.

In deep and warm mines, where large volumes of air are constantly circulating, any limited amount of moisture such as this is soon absorbed.

The capacity of air for holding moisture in the form of aqueous vapour increases as its temperature rises, unless, therefore, air circulating in a deep and warm mine absorbs moisture in its passage through the mine, its dryness increases with its rise in temperature. The moisture accompanying the issue of gas ceases in a short time, and main roads and old roads in the pillars may be looked upon as free from this source of moisture.

In the absence of permanent issues of water in a deep mine the working face of the whole or first workings is the main source of moisture; the pillar workings being in coal, already partly drained, do not afford the air much moisture.

The shafts are rarely dry, the main feeders of water are usually tubbed off, but sufficient moisture appears to be present in most shafts to nearly saturate the air in its descent.

The current of air, as it approaches the working faces of deep mines, rises in temperature and assumes at the face its normal degree of heat—a temperature approximating closely to that due to the depth; if the main intake and haulage road is free from large permanent sources of water, the air on this road becomes drier as it nears the face. While passing the working face, and especially in the first working of the board and pillar system and longwall faces, the air picks up moisture from the coal, and enter the return air road more humid than on its arrival at the face.

In deep mines the normal temperature is above that on the surface, except during part of the hottest days of summer; during these periods the air is reduced below the temperature of the mine during its descent of the downcast shaft, rising again in temperature as it traverses the intake air ways.

In shallow mines, during warm weather, cooling takes place both in the shafts and intake air roads; and in such pits, roads that are comparatively dry in cold weather, when the normal temperature of the mine is in excess of that of the surface, exhibit the following phenomenon during warm days. The air being reduced in temperature while passing along the intake air roads, deposits moisture, which collects in large drops on the roof and sides. Shallow mines are much troubled with falls of stone on the intake air ways during warm weather, as the water deposited by the air getting into the crevices of the stone loosens it.

Notwithstanding the large currents of air passing along the intakes of deep mines for years, and absorbing heat from the rock and coal, the temperature of the air on such roads does not appear to fall much as time proceeds.

During cold weather the air enters the intake air roads at a lower temperature than in warm weather, and as it ultimately attains the same degree of heat on its approach to the working face, its drying power is greater during the colder months, and greater during the night than during the day.

The following tables showing the hygrometrical condition of the air in Durham Collieries, are taken from the Report of the Commissioners on Coal, dated 1871 :—

HYGROMETRICAL OBSERVATIONS, &c., BY MR. L. WOOD.

Colliery.	Date.	Situation.	Dry Bulb.	Wet Bulb.	Difference.	No. of men and boys the air has passed over.	No. of horses and ponies the air has passed over.	Barometer.	Quantity of air, in cubic feet, per minute.	Depth below surface, in feet.	Distance the air has travel'd from downcast shaft, in yards.
			° F.	° F.							
Eppleton	13 Oct., 1869.	Surface, 4·30 a.m.	50	47½	2½	..	..	30·24	..	..	..
		Surface, 1 p.m.	56½	51½	5	..	..	30·55	..	..	..
		Intake air, Hutton Seam—									
		Shaft siding	61	61	0	..	..	31·10	78,720	1,100	312
		1st North way end.. ..	65¾	64½	1¼	..	..	31·30	38,850	1,270	955
		6th South way end.. ..	67¾	66	1¾	..	..	31·45	21,000	1,388	2,296
		8th South way end.. ..	69	67½	1½	..	..	31·52	11,550	1,450	2,925
		Outbyeside putting station	72	70½	1½	5	5	31·50	4,500	1,395	4,130
		Working face—									
		Wagonway jud	73½	73½	0	13	10	31·52	..	..	4,332
		3rd West way	74	74	0	17	10	31·60	..	..	4,440
		High board	74½	74½	0	21	10	31·60	..	..	4,560
		Return air—									
		West way doors	74	73	1	..	..	31·60	4,500	1,420	5,638
		6th South crossing ..	72½	71½	1	..	..	31·65	8,520	1,388	6,848
		4th South crossing ..	72½	71	1½	..	..	31·57	12,750	1,340	7,530
		Main return..	70	68	2	..	..	31·33	67,500	1,100	8,750
Eppleton	23 Oct., 1869.	Surface	52½	51½	1	..	..	29·80	..	..	..
		Intake air, Hutton Seam—									
		Main intake shaft siding..	57½	57	½	..	..	..	52,200	1,100	312
		1st North way end.. ..	62½	60½	2	..	..	..	28,140	1,270	955
		6th South way end.. ..	65½	63¼	2¼	..	..	..	15,510	1,388	2,296
		8th South way end.. ..	67½	64¾	2¾	..	..	..	9,000	1,450	2,925
		Outbyeside 8th South putters' station	71½	70	1½	..	..	..	3,240	1,395	4,130
		Working face—									
		Wagonway jud	75	74½	½	..	..	..	..	..	..
		3rd West jud	73	73	0	..	..	..	..	..	4,440
		High board	74	73½	½	..	..	:	..	..	4,560
		Return air—									
		West doors	73	72½	½	..	..	..	3,000	1,420	5,638
		6th South crossing.. ..	72	71	1	..	..	..	7,620	1,388	6,848
		4th South crossing.. ..	72	71	1	..	..	..	10,800	1,340	7,530
		1st South way end	69½	68	1½	..	..	..	12,080	1,270	8,150
		Main return	69	67½	1½	..	..	..	44,550	1,100	8,750
Eppleton	20 Oct., 1869.	Surface, 4·30 a.m.	31½	31	½	..	..	29·60	..	..	..
		Intake air, Main coal—									
		Main intake	44	42	2	..	..	..	55,440	850	110
		1st North way end.. ..	50	48	2	..	..	..	30,360	922	572
		5th North way end.. ..	59	56½	2½	..	..	..	15,792	1,035	1,780
		5th North way	62	60½	1½	8	8	..	7,800	1,020	2,800
		5th South way end.. ..	62½	60½	2	4	4	..	7,830	1,008	2,705
		Bishop way end	59½	58¾	¾	3	..	..	7,590	860	1,960

HYGROMETRICAL OBSERVATIONS.—*Continued.*

Colliery.	Date.	Situation.	Dry Bulb.	Wet Bulb.	Difference.	No. of men and boys the air has passed over.	No. of horses and ponies the air has passed over.	Barometer.	Quantity of air, in cubic feet, per minute.	Depth below surface, in feet.	Distance the air has travel'd from down-cast shaft, in yards.
Eppleton —*Contd.*	20 Oct., 1869.	Working face—	° F.	° F.							
		Bishop way end	64	64	0	7	3	..	..	838	2,560
		5th North-east face ..	65½	65	½	10	8	..	..	1,040	3,364
		5th North-west face ..	65½	65	½	13	8	..	..	1,012	3,328
		5th South-east face ..	65	65	0	17	7	..	..	1,030	3,365
		5th South-west face ..	..	..	..	..	..	..	..	..	..
		Return air—									
		5th North-west return ..	64½	64	½	15	8	..	4,200	1,012	3,480
		5th North-east return ..	66	66	0	12	8	..	5,425	1,040	3,720
		5th South-west return ..	63	62½	½	8	6	..	2,500	1,000	2,840
		5th South-east return ..	65½	65½	0	21	7	..	4,000	..	3,535
		4th North crossing.. ..	64	64	0	..	..	..	13,750	988	3,960
		2nd North cross-cut ..	63½	63½	0	..	..	..	15,900	936	5,264
		Bishop way return.. ..	62½	62½	0	9	3	..	4,000	860	2,950
		Top of north drift.. ..	63	63	0	..	..	..	28,000	850	5,790
		Top of south drift	63	63	0	..	..	..	18,000	850	5,870
Eppleton	17 Oct., 1869.	Surface, 4·45 a.m.	46	46	0	..	..	30·12	..	..	..
		Intake air, Main coal—									
		Main intake	55	53	2	..	..	30·80	55,440	850	150
		1st North way end.. ..	58½	57	1½	..	..	30·90	32,750	922	172
		5th North way end.. ..	61	59½	1½	..	..	31·05	13,200	1,035	1,780
		5th North face	64	63½	½	4	4	31·05	..	1,020	2,800
		5th South face	63½	63½	0	6	6	31·05	..	1,008	2,700
		Return air—									
		4th North crossing.. ..	64½	64½	0	..	..	31·02	10,800	988	3,960
		2nd North crossing ..	64	64	0	..	..	31·00	12,250	936	4,850
		Top of north drift.. ..	63	63	0	..	..	30·75	31,050	845	5,790
		Top of south drift.. ..	63	63	0	..	..	30·75	23,100	845	5,870
Elemore ..	19 Oct., 1869.	Surface, 4·30 a.m.	38	38	0	..	..	29·15	..	..	..
		Surface, 11 a.m.	35	35	0	..	..	29·36	..	..	..
		Intake air, Hutton Seam—									
		Bank head	50	48	2	..	..	..	24,480	866	100
		1st South way end.. ..	57	53½	3½	..	..	..	4,000	894	858
		2nd South way end ..	61½	60	1½	4	4	..	4,000	890	1,350
		East way	60	58	2	6	5	..	6,000	962	1,760
		Working face—									
		East way end	67½	67½	0	12	6	..	..	970	1,860
		Spout way end	66	66	0	15	8	..	..	935	2,660
		Return air—									
		2nd South return	62	61½	½	12	4	..	4,000	890	1,560
		Spout way return	64½	63½	1	18	8	..	..	935	2,924

Hygrometrical Observations.—*Continued.*

Colliery.	Date.	Situation.	Dry Bulb.	Wet Bulb.	Difference.	No. of men and boys the air has passed over.	No. of horses and ponies the air has passed over.	Barometer.	Quantity of air, in cubic feet, per minute.	Depth below surface, in feet.	Distance the air has travel'd from down-cast shaft, in yards.
Elemore—*Contd.*			° F.	° F.							
		Return Air—									
		Spout way return	65	64	1	..	..	..	5,600	941	3,300
		2nd South return	64	62½	1½	..	..	..	6,090	871	4,400
		Main return	63½	61½	2	..	..	..	21,630	850	5,320
Elemore ..	18 Oct., 1869.	Surface	35½	35	½	..	..	29·97	..	..	..
		Intake air, Hutton Seam—									
		Bank head	48½	46½	2	..	..	30·73	14,976	866	100
		2nd South way end ..	56	53½	2½	..	..	30·75	11,880	894	858
		East way	59	57	2	9	9	30·86	4,000	962	1,760
		Return air—									
		Spout way	65	63½	1½	..	..	30·75	5,640	941	3,300
		2nd South way	64½	62½	2	..	..	30·72	6,090	871	4,444
		Main return	63½	62	1½	..	..	30·60	21,630	850	5,320
Harton ..	27 Oct., 1869.	Surface	39	35	4	..	..	29·50	..	..	..
		Intake air—									
		Bottom of pit	48	45	3	..	..	..	25,125	1,260	80
		Top of drum, bank ..	63	60½	2½	..	..	..	15,000	1,062	1,782
		5th South way end	64½	63	1½	31	10	..	5,000	882	3,168
		Working face—									
		5th South face	65	64½	½	39	16	..	..	882	3,454
		East face	64½	64	½	50	19	..	..	900	4,246
		2nd South face	68	67	1	62	23	..	..	924	3,696
		Drift way face	71¾	70	1¾	13	3	..	..	1,254	1,826
		Return air—									
		North return	66½	65½	1	..	..	..	5,000	978	5,104
		South return	67	65½	1½	..	..	..	6,800	978	5,280
		Standage	66	66	0	..	..	..	7,140	1,272	6,732
Wearmo'th	25 Oct., 1869.	Surface	45¼	43	2¼	..	..	..	..	..	..
		Intake air—									
		Bottom of pit, Hutton Seam	56½	54¼	2¼	..	..	32·00	38,250	1,676	80
		Big bank	58	56	2	..	..	..	33,250	1,536	1,020
		Bottom of big bank ..	63	58½	4½	..	..	..	71,500	1,646	1,430
		South way	75¾	71½	4¼	10	10	..	5,000	1.638	2,850
		Working face—									
		West side gateway	81¾	79½	2¼	18	12	..	..	1,646	3,256
		East side gateway	82¼	81¼	1	37	21	..	..	1,640	3,216
		Return air—									
		Bottom of trouble	80	74½	5½	..	..	..	20,600	1,640	4,500
		Main return	77	74	3	..	..	..	83,500	1,536	6,240
		Main return at furnace ..	77	74	3	..	..	..	90,500	1,560	7,300

HYGROMETRICAL OBSERVATIONS.—*Continued.*

Colliery.	Date.	Situation.	Dry Bulb.	Wet Bulb.	Difference.	No. of men and boys the air has passed over.	No. of horses and ponies the air has passed over.	Barometer.	Quantity of air, in cubic feet, per minute.	Depth below surface, in feet.	Distance the air has travel'd from downcast shaft, in yards.
			° F.	° F.							
Ryhope ..	2 Nov., 1869.	Surface	50	48	2	..	..	..	..	..	..
		Intake air—									
		Bottom of pit	55	54½	½	..	..	..	59,210	1,524	80
		Engine landing	61	57½	3½	..	..	..	27,440	1,644	946
		Outbyeside flat	69½	67½	2	10	10	..	6,000	1,548	2,600
		Working face—									
		North side board	73	71	2	21	16	..	..	1,560	2,762
		Return air—									
		South-east return	75½	73	2½	..	..	..	12,450	1,566	4,110
		Main return at furnace ..	73½	69	4½	..	..	..	32,000	1,524	5,453
Murton ..	3 Nov., 1869.	Surface	50½	50	½	..	..	..	..	..	..
		Intake air..									
		Bottom of pit	54	53½	½	..	..	..	76,160	1,339	410
		1st Engine landing ..	64	59	5	..	..	..	24,250	1,365	2,332
		Outbyeside flat	70	69½	½	..	..	..	1,600	1,374	4,400
		Working face—									
		Shotton cross-cut way ..	70	69½	½	..	..	..	..	1,374	4,532
		Return air—									
		Near working face.. ..	73½	73	½	..	..	..	1,600	1,374	4,960
		Main return..	71	68½	2½	..	..	..	15,600	1,387	7,842
		Main return at shaft ..	68½	68	½	..	..	..	25,500	1,399	8,777
Wearmo'th	29 Mar., 1870.	Surface, noon	41	40	1	..	..	..	..	..	..
		Surface, 4 p.m.	42½	40	2½	..	..	..	..	..	..
		Bottom downcast, noon ..	51	47	4	..	..	..	..	1,676	..
		Bottom downcast, 4 p.m. ..	50	47	3	..	..	..	..	1,676	..
		South way end	66	60	6	..	..	..	..	..	2,134
		1st West way outbyeside putting station, 1 p.m. ..	73	68	5	..	..	..	..	1,638	2, 50
		1st West way outbyeside putting station, 3 p.m. ..	74	60	5	..	..	..	..	1,638	2,850
		North flat of west way ..	81	78	3	..	..	..	..	1,646	3,112
		East side gateway, last of air	81	78	3	35	..	..	..	1,640	4,030
		East side gateway, out of air current	82	81	1	..	..	..	..	1,640	4,030
		Bottom of 13 fathom trouble	81	75	6	..	..	..	..	1,640	5,218
Seaham ..	1 April, 1870.	On the surface..	55	51	4	..	..	..	..	..	..
		Bottom downcast shaft, Hutton Seam	55½	53	2½	..	..	..	50,000	1,686	..
		East way end	57	53½	3½	..	..	..	50,000	1,801	660
		East way engine station, outbyeside of putting station	67	59	8	..	..	..	12,000	1,995	1,850
		East flat, south side, last of air after passing working face	78	67½	9½	..	19	..	5,000	1,995	2,200
		North headways, return ..	78	69	9	..	22	..	10,000	1,851	3,400
		East way return air	80	71	9	..	..	..	..	1,800	4,000

The following observations were made by the writers:—

Colliery.	Date.	Dpth.	Situation.	Dry Bulb.	Wet Bulb.	Difference.	Remarks.
		Feet.		°F.	°F.		
Usworth ..	Nov. 4, 1885	..	Surface	45½	42	3½	Observations taken between 11 a.m. and 2 p.m.
		960	Bottom downcast	50	49	1	
			Intake 792 yds. from shaft	58½	56½	2	
			„ 1,892 „ „ „	63	59½	3½	
			„ 2,170 „ „ „	69½	63½	6	Top of stone drift.
			„ 2,240 „ „ „	69½	63½	6	Place where shot was fired.
			Return near upcast	67½	63½	4	
Usworth ..	Jan. 19, 1886	960	Bottom downcast	36	36	0	12·30 p.m.
Washington	Nov. 18, 1885	..	Surface	37	36½	0½	White frost.
		600	Bottom downcast	53	50	3	Observations taken between 11 a.m. and 2 p.m.
			Intake 1,000 yds. from shaft	58	54	4	
			„ further from shaft ..	65	64	1	
			Face	66½	66	0½	
			Return	63	60½	2½	
So. Tanfield	Nov. 25, 1885	..	Surface	39	38½	0½	Observations taken between 11 a.m. and noon.
		784	Face near shafts	51½	49½	2	3/4 Seam opening out.
So. Tanfield	Nov. 25, 1885	474	Bottom downcast	46½	44½	2	Observations taken between noon and 1 p.m.
			Intake 400 yds. from shaft .	52	50½	1½	Main Coal Seam.
			Face	55½	55½	0	
Urpeth ..	Dec. 2, 1885	..	Surface	45½	42½	3	Observations taken between 11 a.m. and 1 p.m.
		690	Intake 120 yds. from shaft..	57½	57	0½	
			„ further „ „ ..	58	57	1	
			„ „ „ „ ..	63	62½	0½	
			Face	60	59	1	
			Return	61½	60½	1	
Saint Hilda	Dec. 3, 1885	..	Surface	42	39	3	Observations taken between 11 a.m. and 2 p.m.
		960	Bottom upcast..	65½	65	0½	Intake air.
			Intake	63	58½	4½	
			„	64	60	4	
			„	69½	65	4½	
			„	69	65½	3½	
			Face	70	67	3	
			„	70½	67½	3	
			Return	71	68½	2½	
Wearmouth	Jan. 6, 1886	..	Surface	36	33	3	Observations taken between 11 a.m. and 2 p.m.
		1,722	Bottom downcast	44½	42½	2	
			Intake 1,300 yds. from shaft	55	51½	3½	
			„ 2,500 „ „ „	60½	55½	5	
			„ 3,200 „ „ „	65	59	6	
			Return	75	70½	4½	
Blaydon Burn	Jan. 15, 1886	..	Surface	42½	40	2½	Observations taken between 11 a.m. and 1 p.m.
		135	Bottom downcast	42½	41½	1	
			Intake 500 yds. from shaft..	51	50½	0½	
			„ 900 „ „ „ ..	54	54	0	
			Face 1,400 „ „ „ ..	54	54	0	

Colliery.	Date.	Dpth.	Situation.	Dry Bulb.	Wet Bulb.	Difference.	Remarks.
				°F.	°F.		
Felling ..	Mar. 9, 1886	..	Surface	31½	29½	2	Observations taken between 11 a.m. and 1 p.m.
		606	Intake 200 yds. from shaft ..	41	40½	0½	
			Return	72	71	1	
Ryhope ..	Nov. 23, 1885	..	Surface	44	43½	0½	
		1,594	Intake 50 yds. from shaft ..	51½	49	2½	Maudlin Seam. Observations taken between 10·30 a.m. and 2 p.m.
		1,644	Face 4,690 „ „ „ ..	81½	81	0½	
		„	„ „ „ „ „ ..	79½	79¼	0¼	
		„	„ 4,160 „ „ „ ..	78½	78½	0	
Ryhope ..	Nov. 24, 1885	1,524	Intake 50 yds. from shaft ..	52½	49½	3	Maudlin Seam. Do.
		1,404	Face 3,210 „ „ „ ..	69	68½	0½	
		„	„ „ „ „ „ ..	72	71½	0½	
Ryhope ..	Nov. 25, 1885	1,674	Intake 1,892 yds. from shaft	76½	62½	14	Hutton Seam. Do.
		1,704	Face 2,270 „ „ „	77	72½	4½	
		1,764	Intake 2,000 „ „ „	70	63	7	
		„	Face 2,330 „ „ „	81	79	2	
Ryhope ..	Mar. 31, 1886	..	Surface	46	44	2	
		1,626	Bottom downcast	52½	50	2½	Hutton Seam.
			Intake 800 yds. from shaft	65	57½	7½	
			„ 1,600 „ „ „	76	62	14	
			„ „ „ „ „	77½	66½	11	
			Face 2,400 „ „ „	80½	75½	5	
			Return 800 yds. from face	80	68½	11½	
			„ 1,600 „ „ „	79¼	67½	11¾	
			„ 2,400 „ „ „	76	66	10	
Silksworth ..	Nov. 30, 1885	1,620	Intake 60 yds. from shaft	54½	51	3½	Maudlin Seam.
		1,589	Face 3,520 „ „ „	74	74	0	
		1,515	„ 3,410 „ „ „	77	77	0	
		1,340	„ 3,762 „ „ „	70	68½	1½	
	Nov. 26, 1885	1,740	Intake 135 yds. from shaft	55	52	3	Hutton Seam.
		1,557	Face 2,650 „ „ „	72	64½	7½	
		„	„ „ „ „ „ „	75	70	5	
	Nov. 30, 1885	1,778	Face 1,100 yds...	69	65½	3½	Hutton Seam.

Coal dust in mines may be roughly divided into two classes:—

1st.—The dust on the floor, which will be spoken of as bottom dust.
2nd.—The dust on the sides, top, and timber, which will be spoken of as upper dust.

On dry haulage roads, where dry and dusty coal is led, and more particularly where it is led by engine power, coal dust is shaken out and flies as a cloud along the tops of the tubs, which are almost invariably passing against currents of air on the intakes. The air passes through tubs that have holes in them. The dust is carried away with the air from the tubs and the heavier particles fall to the bottom or lodge nearest the bottom. The lighter particles form a deposit on the upper parts of the roads as well as on the floor.

Coal dust sometimes exhibits the property of sticking to timber, stone, and coal, something like soot hanging in a chimney; that is, a deposit once formed, it grows, particles already deposited appearing to entangle other particles. Coal dust does not adhere to coal surfaces, which are often bright and smooth, so readily as to timber or stone; and to rough stone it adheres, more than to a natural parting in the stone. This hanging dust is sometimes spoken of by miners as soot.

The deposits of the upper dust appear to exist in greatest quantity for about 3 feet in height above the tops of the tubs. The tubs stand about 3 feet high, so that in a haulage road 6 feet high the upper 3 feet contains the most upper dust. In cases where the road is, say, 10 feet high, it is observed that from the floor to the tops of the tubs there is not much dust; for 3 feet above the tops of the tubs there is much dust, and the remaining distance is often comparatively free from dust.

Upper dust is by no means confined to deposits resting on horizontal surfaces, such as the upper sides of timbers, ledges, etc.; it has been observed two inches deep on vertical surfaces, and on the under side of timber and stone next the roof. It lies heaped up on all flat surfaces. All this dust is swept off during an explosion, and the appearance of a pit as regards dust, after an explosion, is no guide to its position before.

The upper parts of stone drifts, in which there is no timber, and arched lengths of haulage roads are sometimes lined one or two inches thick with coal dust.

In a stone drift to be mentioned, at Usworth, the conditions appear to have been very favourable for the deposition of upper dust. The drift was of about 40 square feet area, and 26,700 cubic feet of air passed down it per minute. Allowing 6 square feet as the area of the ends of the tubs, which were drawn up it laden with dry and dusty coal, at a speed of about 6 miles per hour, it results that the air moving in-bye would pass over the tubs at a velocity of 834 feet per minute, and as the tubs moved out-bye at a speed of 526 feet per minute, it would be equal to a velocity of 1,360 feet per minute. These conditions would ensure dust being blown out of and from the tops of the tubs, which, being carried back, would form a deposit of upper dust on the sides and top.

It might be thought that such a velocity of air would sweep away dust, but this is not so; the writers have frequently observed dust deposits on the upper parts of roads where the air passing in-bye and the tubs passing out-bye had greater velocities than those mentioned.

The high velocity of the air, within the limits likely to exist in the ordinary circumstances of a colliery, is more likely to cause deposits of upper dust than a low velocity; the eddies caused by the passage of a train of tubs against a large current of air ensures a considerable quantity of coal dust being carried against the upper parts of the road, where some of it sticks.

The writers have, years ago, frequently ridden out on an engine set of laden tubs at a colliery in the County of Durham, and in doing so it was necessary to cover the head with a handkerchief as a protection from the cloud of dust flying back.

In addition to dust from the top of the tubs a quantity of dust and small coal is shaken out of the bottom and sides of imperfect tubs.

The dust collecting on the floor of the haulage roads in dusty pits has frequently to be removed, otherwise the road would become blocked; this removal of dust has no reference to upper dust, which is not interfered with.

Mr. Galloway has stated* that 1 lb. of dust to 160 cubic feet of air is necessary in order to form an inflammable mixture. Assuming 40 square feet area, then 1 lb. of dust is required for each length of 4 feet, or $\frac{1}{4}$ lb. for each foot. On dry and dusty haulage roads a quantity of dust in excess of this often exists as upper dust only, not considering bottom dust, and this over long lengths of road.

On the horse roads the quantity of upper dust is usually much less than on the engine planes. The tubs move at a lower speed against smaller currents of air, and the quantity of coal led over individual horse roads is less in quantity than that passing to the shafts on the engine planes, the horse roads being feeders to the engine plane. A considerable quantity of bottom dust exists on the floors of the horse roads, often greater in quantity than on engine planes. This bottom dust is, however, often much mixed with stone dust ground up by the horses feet from the bottom stone of the seam; horse dung and other impurities are mixed with it, and although it may contain a large quantity of coal dust, the latter cannot be collected separately.

The working places and the roads over which putters pass with single tubs are comparatively free from upper dust, and the quantity of coal dust is less generally, than on the horse roads and engine planes.

The dust in the air is considerable at the face of the working places, and, unless the coal is moist, there is frequently much dust on the floor.

The return air roads are, in most collieries in the North of England, free from coal dust. The work done on these roads is more in connection with stone than coal, such as forming pillars of stone and removing fallen stone; so that the coal dust left in them as working places soon becomes so mixed with stone dust as to lose its specific character. The timber supporting the roof in abandoned workings is usually withdrawn, and the roof stone falls and covers the dust left in them as working places, and, no fresh supply being available, these passages are often comparatively free from coal dust.

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* "Transactions of Royal Society," Vol. XXIV.

In some beds of coal, however, where top coal is left, which afterwards falls, or where the coal is of a specially tender character and the sides of the passages constantly fall over, the whole of the return air roads and old workings contain coal dust.

Coal dust in mines is often referred to as constantly present in the air. This is not so, except to a limited extent. The velocity of the air is rarely sufficient to carry dust any considerable distance. Near the shafts, where the velocity of the air is at its maximum, and where dust from the screens on the surface descends the pit, it is probable that the finest particles are carried some short distance along the air ways.

When dust is largely present in the air it is due to some disturbing cause other than the ordinary movement of the air. The rapid passage of tubs against the air current raises a cloud of dust from them; the passage of men and horses stirs up the bottom dust; the hewer at the working face raises about him a thin cloud of dust; the concussion of a shot, or wave of air caused by a heavy fall of stone, fills the air with dust; but in the absence of some such cause the dust is quiescent, and after its disturbance by any cause it soon settles down again.

Coal dust is not carried from the working face into the return air ways.

The coal dust collecting on the higher parts of the haulage roads appears to undergo some change and becomes more readily combustible than fresh coal dust.

Thus the writers have found that upper dust collected from dry collieries in the North of England has the property of burning *en masse*, that is if flame is applied to it so as to heat a small portion to redness, combustion gradually spreads itself through the mass, no flame being visible; ordinary coal dust has not this property.

Upper dust would appear to have undergone some chemical or physical change.

It is possible that absorption of oxygen from the air may have taken place.

Upper dust has a dull brownish cast and is not so distinctly and brightly black as fresh coal dust or screen dust. It forms a very friable coke, the particles under the action of heat do not fuse and adhere readily. This fact may have some bearing on the absence of deposits of coked dust on the haulage roads after explosions; the writers have noticed that deposits of dust on such roads after explosions have some coherence, and this may be due to the dust being really a friable coke.

The greatest amount and extent of violence was always observed on those roads likely, before the explosion, to contain most upper dust.

The inflammable nature of dust on roadways of collieries is well known and has been the cause of several fires. The dust has been ignited by a shot or by the "snot" from a lamp being thrown amongst it. In some collieries nothing but safety lamps are allowed to be used on the haulage roads, in order to prevent the ignition of the dust.

There is much difference in coal seams as to their capacity for producing dust. Until the coal is dry no judgment can be formed as to this. A tender coal produces more dust than a hard coal. Coal worked from the pillar workings is, as a rule, drier than coal from the whole workings, and is more tender owing to the crushing of the pillars.

Some coal seams are filled in with deposits of white spar—all the cleats contain vertical sheets of spar; when this is present the coal seldom produces much dust. Thus the steam coal of Northumberland is characterised by this spar and is not dusty.

All coal seams are divided into sections by horizontal partings and a dull black substance, which soils the fingers, accompanies these partings: this is called "dant," and sometimes "mother of coal;" a large quantity of the dust blown from the tubs will be "dant." It is possible that an examination of this substance might reveal some facts bearing on the subject of explosions.

Deep mines being warmer than shallow mines, coal dust accumulates in them. Fire-damp is also more common in deep than in shallow mines, owing to the superincumbent strata preventing its escape to the surface.

Coal dust and fire-damp thus accompany each other, but for different reasons.

It is possible, however, that strata charged with fire-damp at high pressure will not contain moisture that might, in the absence of fire-damp, have been present in quantity sufficient to cause dampness.

Fire-damp does not increase in quantity with the depth, but may be said to be an approximately constant quantity after a certain depth is reached, and this depth coincides roughly with the depth at which the temperature of the strata is such as to cause dryness.

Examples, however, are not wanting of deep and fiery mines where water is present in such quantity as to prevent any accumulation of dust, and also of mines of depth sufficient to cause dryness, but yet so free from fire-damp as to be worked with naked lights.

In order to arrive at a conclusion as to the origin of the explosions and their extent, the writers noted the following :—

Parts traversed by force, and the direction in which the force had passed.

Parts traversed by flame.

Position and occupation of the workmen on the plane and district of explosion, and the position of all lights and fires.

Plans 2 show the parts of the collieries over which the explosion had passed with violence and flame. Arrows show the places where evidences of force were observed and the direction of the force. The letter F in red shows where signs of fire or burning were observed.

The positions in which the bodies of the workmen were found are shown by dots on Plans 1.

The solid stone and coal bounding the roads is rarely affected by the force of the explosion. A judgment as to the force exerted and its direction may be formed by an examination of timbering, tubs, doors, stoppings, and air crossings; rails, machinery, and boilers, supports and sheaves for ropes and wires; workmen's lamps and tools, shaft timbering and cages, men and horses, dust, hay, and other light material.

In consequence of the timber put in to support the roof being blown out, falls of stone are very general in pits after explosions ; these falls are caused by the stone resting on the timber being deprived of support. Where no timber had been required the roads were not affected by falls of stone after the explosion. In some instances the falls were so extensive that they could not be passed over, and where the fallen stone was soft and in small pieces, the main intake was completely closed, even to the passage of air. The timber under these falls as well as other things being covered up, indications as to the direction of force were lost.

With regard to falls of stone an important point is noticed ; where timber is blown out and some stone falls at once and during the explosion and other stone falls some time after and may continue falling for days, the stone falling at the time of explosion can be known by the fact of its being blackened with dust then filling the air. The place from which the stone fell can also be known by this blackening. Stone falling after the dust has subsided is in the newly exposed surfaces clean, as also is the place from which it fell. Thus, in a pit after an explosion, we find stone with three characteristics as regards dust :—

1.—Stone exposed before the explosion and usually blackened with the remains of an old coating of dust.

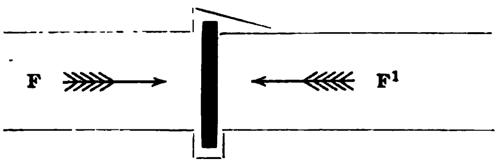
2.—Stone exposed during the explosion and coated thinly with a fresh coating of dust.

3.—Stone exposed after the explosion and clean as regards dust.

Important reasoning can often be based upon observations of this nature.

Timbering sometimes affords good indications as to force and direction, but this is most so when part of it only is blown out. One of the commonest forms of timbering is two props and a balk across them. When one prop is blown out and the balk forced from its original position on its supported end, a good indication is afforded as to direction of force.

A form of timbering on haulage roads, called the hole and driving end, is often a good indication. A force F would blow the balk down, a force F^1 would not move it.



PLAN.

Tubs give very good indications both as to direction and amount of force. Full tubs are more broken near the top and above the level of the coal in them. Empty tubs are often completely smashed, but afford undoubted indications as to direction of force.

Stoppings when stowed are not generally moved, except near the top. Unstowed stoppings of brick or stone, unless very thick, are easily moved, and afford good indications as to direction of force, but not so good as to the amount. A 9-inch brick stopping is sometimes blown down by heavy gusts of air caused by an extensive fall of stone in the ordinary working of a pit; they are not erected to withstand lateral pressure.

Doors, like stoppings, afford indications as to direction of force, but not as to amount of force. Doors are blown out by a force that will not move timber, break up tubs, or injure men.

Machinery affords grounds for a judgment as to the violence of force, but perhaps not so good as to its direction. The parts are broken but often not moved far.

Supports for hauling ropes and rapper wires afford indications of the passage of force and its direction, but as force may be transmitted by the ropes or rapper wires from distant points, indications connected with these supports must be cautiously examined, and all sources of transmitted force eliminated as far as possible before coming to any conclusion.

Workmen's tools and lamps afford some indication as to the passage of force or the reverse.

Damage to shaft timbering usually occurs at the limit of an explosion, but the varying extent of this damage appears to show that the explosion in some cases continues up the shaft.

The deposit of dust on timber and other things affords an indication as to direction, which, the writers think, is usually misinterpreted. With ordinary coal dust, coked dust, generally spoken of as charring, may be included.

This matter was more fully investigated at Usworth than at any of the other explosions. At Whitehaven there was no dust.

As stated in the description of force and flame at Usworth, observations were made in more than twenty instances. The direction of the blast was, in most of these cases, not a matter of any doubt whatever. It appears from these observations that dust, either as dust or as coke, is generally deposited on the sides of the props, etc., opposite to the direction of the blast. The deposition will probably take place during a reverse current instantly succeeding the explosion, and other reasons for supposing the existence of this reversed current are given.

Plans 2 show the parts of the collieries over which flame has passed. The evidences as to the passage of flame are:—

Burning of men and horses.
Coking of dust.
Burning of timber, hay, brattice cloth, etc.
Fires discovered after the explosion.
Evidence of survivors.

The burning of men and horses is more apparent by the frizzled state of the hair than by anything else, so far as an ordinary observer is concerned. The bodies of men, in the field of an explosion in dusty pits, are always blackened, and the extent of the burning they have been subjected to is a matter on which a medical man only can speak with any degree of confidence.

The coking of the dust is an indication often wanting over long lines, where great force and flame have passed. It is more noticed at the working faces than on the haulage roads. It was not observed at the shaft limit of an explosion. A chemical and microscopical examination of dust on haulage roads, in the absence of coking, affords reasons for asserting the passage of flame.

Timber, hay, brattice cloth, and other substances readily inflamed, are found burnt after an explosion, or burning when near the limit of an explosion, or where fresh air is directly afterward available to support combustion. Where the explosion has passed over long lengths of road, the whole of the oxygen in the air will be consumed, and further combustion rendered impossible, unless fresh air returns at once to the inflamed bodies.

The position and occupation of the workmen on the plane, and in the district of the explosion, and the position of all lights and fires, is important, as the origin of the explosions must be referred to a light carried or used by a workman, a fire existing before the explosion, or the flame of a shot.

The cause of death should also be noted. Information on this head is usually supplied by medical men, but is sometimes unsatisfactory, as they are not aware of the conditions under which the bodies were found, nor of the sequence of events which preceded and followed the deaths.

An extensive explosion is accompanied by four conditions, any one of which could ultimately cause death :—

Flame.
Force of the explosion.
Falls of stone and timber, caused by the force of the explosion.
After-damp.

At the origin, and at the working faces, where the explosion extends to them, the victims are burnt, but their bodies are usually not mutilated, unless from special causes.

The distance they move is never, under these conditions, more than a few yards; and it would appear that after-damp is the immediate cause of death. Examples are noticed of persons who have been near the origin, or at the face limit, of an explosion, and who have escaped burning almost entirely, but yet have evidently succumbed within a few yards of the place where they had been before the explosion—after-damp having caused death in a very short time.

Persons near the shaft limit of an explosion, who have been subjected to both violence and burning, and who have not moved after the explosion, are sometimes found alive. They had escaped death by after-damp owing to fresh air returning at once to them. This would appear to show that burning or violence alone, or in conjunction, is not necessarily sufficient to cause immediate death; and therefore, where a victim is much burnt, but who has evidently succumbed within a few yards of his working place, after-damp has probably been the immediate cause of death.

Where victims have been subjected to the full force and flame of the explosion at some distance from the shaft, they are found mutilated and burnt, and often buried under falls of stone, and have not moved further than the explosion might have blown them. It would be impossible to say whether violence or after-damp had been the immediate cause of death in such cases; but it would be certain that after-damp alone would have caused nearly immediate death, even if they had escaped death by violence. The stone under which they were found may not have fallen until after death.

The victims outside the field of the explosion, and who escape both violence and burning, die from after-damp alone.

It would appear that the immediate cause of death is, in almost all cases, after-damp. Victims exposed to violence and burning would be, unless near the shaft, also so exposed to after-damp that the latter alone would cause almost immediate death.

Persons found alive near the downcast shaft, and who, owing to its proximity, have escaped death from after-damp, often die in a day or two from the effects of the violence and burning they have been subjected to.

There is another condition that may be the cause of death in some cases: the air in the field of an explosion is often so filled with dust as to cause suffocation; thus the mouth of one of the victims of the Usworth explosion was observed by the doctor to be full of coal dust.

The report by a doctor as to the injuries and burning of each victim of an explosion is very necessary; important conclusions can sometimes be drawn from the character of the injuries.

The relation between workmen and their lights must be discussed. Ordinary workmen using a safety lamp and working in a limited area, such as hewers, stonemen, shifters, etc., always hang their safety lamps within a short distance of their place of work, on an average from 3 to 6 feet distant. They sometimes have a nail attached to the ring of their lamp, which they knock into a prop or any timber near. The hewers are generally provided with a lamp stand on which they hang their lamps, and sometimes the lamp is placed on the floor. Workmen whose work necessitates constant motion, such as officials, putters, drivers, etc., carry their safety lamps with them, when at rest hanging the lamp by a nail or setting it on the floor. A miner using a safety lamp or any description of light is rarely any considerable distance from it; he carefully guards it and seizes it on the first symptom of alarm.

In dusty collieries, after extensive explosions, the following relation between workmen and their lamps is observed:—

a When the workman has been traversed by great force and flame the lamp is usually found blown down and injured, and not far from the owner.

b Where the workman has been traversed by flame, but no great force, the lamp is found hanging where it was before the explosion, and the workman a few yards from it, unless he has been in motion at the time of the explosion, or has retired from his place of work to fire a shot, in which cases the lamp is either with him or at the point to which he has retired, usually upset and covered with oil.

c Where the workman has been out of the field of the explosion, but sufficiently near it to extinguish his lamp, in this case the lamp is found hanging at the place of work and the workman some distance from it, having passed out in the dark until he perished from after-damp.

d Where the workman has been traversed by no flame and no force or any gust of air sufficient to extinguish his lamp, in this case the workman and lamp will be found together at the point where he has perished from after-damp, and some distance from his place of work. The lamp may be found hung up or standing on the floor, the oil in some instances being all consumed, the lamp having continued burning after the death of its owner.

The relation between workmen and those parts of their dress they take off when at work is similar to the relation between them and their lamps.

In fire-damp explosions, without any coal dust being brought into play, the relations discussed are different. The persons at the point of origin frequently escape alive, with burns only, and the movement observed to have been made by all the victims, is far greater than in the case of victims in the field of an explosion in dusty pits.

The task of examining a colliery after explosions, such as those to be described, is most laborious and sometimes dangerous. To have the best chance of drawing correct conclusions from such an examination, it is essential that it made when the mine is first explored, as it is necessary to move many things during the work of restoring the ventilation and recovering the bodies, and this is done with very little observation by the workmen. The whole of the work has to be done by the dim light of the safety lamp, and as operations are carried on continuously by night and day, the same observer cannot always be present.

It is necessary to use considerable caution in drawing conclusions from the indications observed as to the direction in which the explosion has passed. In some cases the most careful examination showed that force had been exerted in opposite directions over the same length of road. In several cases light bodies were moved several yards in what was evidently the contrary direction to that of the explosion.

SEAHAM COLLIERY EXPLOSION.

An explosion occurred at Seaham Colliery, in the County of Durham, on the 8th September, 1880, at 2·20 a.m., causing the death of 164 men and boys and 181 horses and ponies.

The explosion was confined to workings on what is practically one horizontal plane, which at the shafts lay at a depth of 510 yards. The Hutton and Maudlin Seams were worked on this level, the latter seam being thrown down by a dislocation near the shafts to about the level of the former. The Main Coal Seam had also been approached through this trouble, but at the time of the explosion no workings were being prosecuted in it. Extensive workings were in operation at levels both above and below that on which the explosion occurred: in the Main Coal Seam at 438 yards at the shafts, and in the Hutton Seam at 564 yards on the low side of the trouble already referred to. The explosion was confined to the middle level, and no workmen above or below lost their lives.

There are two shafts at Seaham Colliery. The downcast shaft, 14 feet in diameter, is sunk to the Busty Seam at 600 yards, and is divided into two equal parts by a 3-inch wood brattice. At one side of the brattice coal was drawn from the level of the explosion, and at the other side from the deeper level at 564 yards. This shaft was naturally dry, but water was drawn for a few hours nightly from the lowest level, causing some temporary dampness on one side of the brattice. The upcast shaft, 14 feet in diameter, lies about 150 yards west of the downcast, and is sunk to the level of the explosion, and used for raising coal from that level. Several staples, sunk between the three levels in the vicinity of the shafts, supplement their action.

The general inclination of the measures is moderate, the full rise being nearly due west, about 1¼ inch to the yard.

The colliery was worked, as most Durham collieries are, by two shifts of hewers during the day time, and a shift of repairers and stonemen, with a few hewers, at night. Had the explosion occurred during the time coal was being raised the loss of life would have been much greater.

About 1,500 tons of coal was raised daily from the workings on the plane of the explosion.

The Clanny safety lamp was principally used by the workmen. Some Davy and Stephenson lamps were used.

Gunpowder was not used for blasting the coal, but it was used in stone work, a written authority to fire shots being given by the manager.

Both the Hutton and Maudlin Seams produce fire-damp in considerable quantity. Blowers were sometimes met with in the working faces, more particularly when near dislocations. In the whole or first working gas issued from the coal and was sometimes seen on the lamp. In the broken or second working it was occasionally found near the goaf edge, and at several points in the return air ways fire-damp was given off from old goaves, especially when the barometer was low. They are both very dry seams and produce much coal dust.

The ventilating power of the colliery, consisting of two furnaces and several boiler fires, was on the plane of the explosion. The smoke and heated air ascended two staples to the Main Coal Seam, and passed thence to the upcast shaft. Both the furnaces and some of the boiler fires were fed with return air from the plane of the explosion. So far as is known the furnaces and boiler fires were in their normal condition; furnacemen were in attendance at each furnace and the boiler fires were damped. The total amount of air ventilating the workings affected by the explosion was 184,000 cubic feet per minute. The water-gauge near the downcast shaft was 2·1 inches.

The workings on the plane of the explosion were divided into three principal districts—No. 1 Pit, Hutton Seam; No. 3 Pit, Hutton Seam; and the Maudlin. These districts were approached by three main intake and haulage roads, separating near the downcast shaft. The coal was drawn to the shafts from the landings, marked on plans, by engines, main and tail ropes being used.

The following statement gives the length of air roads and the quantities of air, etc., in these districts :—

Name of District.	Length in Yards of			Average Area of Intake.	Average Area of Return.	Average Velocity of Intake Current before Splitting.	Average Velocity of Return Current in each Split.	No. of Working Places.	Quantity of Air.
	Intake Downcast to Face.	Return Face to Upcast.	Working Face.						
	Yards.	Yards.	Yards.	Sq.ft.	Sq.ft.	Ft. ⅌ m.	Ft. ⅌ m.	No.	Cb.Ft. ⅌ m.
No. 1 PIT, HUTTON SEAM.									
Far off way	2,600	2,800	265	40	50	500	[illegible]	8	20,000
3rd East way, straight east ..	2,850	3,100	300	70	35	143	246	10	10,000
Do. north side	3,375	3,750	1,150	56	50	268	300	16	15,000
Air not going into working faces, as boilers, engine house, stables, etc.	..	..	..	..	..	..	..	..	31,620
Total, No. 1 Pit ..	..	..	..	90	110	718	..	..	76,620
No. 3 PIT, HUTTON SEAM.									
South way	1,100	1,450	190	40	40	342	342	4	13,680
West way	1,250	1,500	..	50	60	260	216	..	12,960
North Main Coal	1,050	1,050	..	25	25	276	276	..	6,930
No. 1 Furnace, leakage, and Maudlin engine	..	..	..	..	..	..	..	..	28,280
Total, No. 3 Pit ..	..	..	..	63	..	950	..	..	61,850
MAUDLIN SEAM.									
West or incline way	2,700	2,900	750	55	60	255	233	28	14,000
East Way	2,100	3,150	350	50	40	300	375	15	15,000
Air not going into working faces, as stables and leakage ..	..	..	..	..	..	..	..	..	16,676
	..	..	..	60	..	760	..	..	45,676
	..	..	..	..	..	..	..	..	184,146

There was nothing unusual in the meteorological conditions at the time of the explosion, as the following observations taken at Seaham Harbour, about a mile from the colliery, will show :—

7th Sept., 9 p.m. Barometer, 30·038. Thermometer, Dry 55·8 deg. F., Wet 52·0 deg. F.
8th „ 9 a.m. „ 30·087. „ „ 57·0 „ „ 53·2 „

From 9 p.m. on the 7th to 9 p.m. on the 8th the maximum and minimum thermometrical readings were 62 deg. F. and 47 deg. F.

The workmen had examined the colliery under the 30th General Rule of the Coal Mines Act two months before the explosion, and found all satisfactory. No unusual source of danger was known to exist, and the examination of the whole colliery by the officials on the day preceding the disaster had pointed to everything being in its normal condition; nothing had alarmed any of the workmen who left the pit before the explosion, nor any who were down and survived it.

When the explosion took place a loud report was heard on the surface, and clouds of dust were ejected from the shafts, but no flame was seen. Owing to damage done to the shafts it was more than 12 hours before a descent could be effected, and then the usual scene of destruction was witnessed by the explorers; doors and air crossings destroyed; tubs broken to pieces and hurled one over another, and everything movable displaced; timber blown out and heavy falls from the roof in consequence, and the bodies of men and horses, in many cases terribly mutilated. Several fires were found burning near the shafts, and these had to be extinguished under circumstances of great danger before the exploration of the mine could be continued. The recovery of the bodies was carried on with unremitting labour, but owing to the numerous difficulties only 136 had been removed by the 1st October, when it was discovered that a fire was burning near the stables in the East way of the Maudlin Seam at a distance of 1,300 yards from the shaft. It was then decided by the mining engineers in charge of the operations to seal off this part of the mine for some time. It was re-opened in June of the following year, and the exploration continued under great difficulties, owing to the workings being full of fire-damp, and the uncertainty of the fire being quite extinguished. Use was made in these operations of Fleuss's patent lamp and breathing apparatus for penetrating dangerous gases; by means of them the explorers were enabled to advance before the air to ascertain if there was any sign of fire, and the lamps were of great service owing to the excellent light which they gave. The last of the bodies was not recovered until exactly a year after the explosion.

The explosion was found to have extended over roads of an aggregate length of about 7,500 yards, the greatest distance between the extreme points reached being about 3,800 yards. It had not extended quite to the face of any district, and was entirely confined to haulage and intake air roads.

The following observations were made of indications of the force and direction of the explosion. The figures refer to Plan 2, where arrows show the direction of the force exerted.

The timber in the downcast shaft (1) was much damaged for about 80 yards above the plane of the explosion. Access to the mine by this shaft was not available until nine days afterwards. Iron lattice fencing at each side of the shaft, and at right angles to the line of the road crossing it, was bulged towards the centre of the shaft from both sides. A disc of sheet iron, forming a guard over a sheave fixed at one side of the shaft, was bent outward from No. 1 Pit. Twelve yards north of the shaft stood a wooden tank, the south end of which was broken and forced into the tank and towards the shaft.

Proceeding into No. 1 Pit, on the south side of the shaft, a number of tubs showed signs of great force having passed inward to the south. The upper parts of some of these tubs were sheared off the trams and carried in-bye, and the angle irons at the corners were, in most cases, bent in-bye. At (2) there was evidence of great force passing off the haulage road towards No. 1 boilers; the regulating doors were blown towards the boilers, and the dampers of the boilers were forced into the flues. At (3) doors were blown to the return. The air crossing here was blown up; bricks from it and from a fall of arching were mostly blown to the north or out-bye. Unburnt hay was also scattered along the road here, evidently from the stables further in. At (4) near the engine house part of the cover of a large wheel was blown in-bye. At (5) tail rope sheaves blown down afforded evidence of force having passed over them as shown by arrow. At (6) the main intake was doubled, one road being used as a haulage road and the other as a travelling road for men and horses, part of the air passing along each road. These roads united again at (7). The passages driven between the haulage and travelling roads in this case, as well as between two such roads in the Maudlin Seam, were stowed close, preventing any force passing between them except at the junctions. The explosion had not traversed the travelling road; at each end, at its junction with the haulage road, disturbance was observed extending a short distance along the travelling road; a blast had shot into each end of it. At (8), about half way along the travelling road, doors leading from it into the return were not moved. Near (9) the wrecks of two cabins by the side of the road showed signs of force passing in-bye. At (10) the out-bye end of a wall of loose stones was swept in-bye. Near (11) five stoppings were blown towards the return; nearly all the other stoppings which were examined were so strongly stowed that they had not been moved. At (12) doors were blown to the return. At (13) a prop was forced in between the hauling rope and a binding sheave, showing force as indicated by arrow. At (14) doors were blown to the return. At (15) the return wheel, at the Third East way end, was moved in-bye. At (16) and (17) tubs were forced in-bye. At (18) the return air road was directly above the intake and haulage road, a brick arch separating them. This arch had been blown up for a length of about fifteen yards and a very large fall of stone had taken place, which was roughly estimated to amount to 400 tons. This fall completely closed the road. The explosion had ceased on this road less than 300 yards beyond the fall; doors there were not blown out.

Returning to the downcast shaft and proceeding into No. 3 Pit; from the shaft to the commencement of the curve, the timber was blown out and some of the roof stone fallen. At (19) was the road leading to No. 1 furnace and upcast staple; the doors here were blown towards the furnace and staple. In the curve no timber had been required, and there was nothing here to afford indications as to the passage of force. At (20), the west end of the curve, timber was displaced on the Maudlin haulage road at its junction with the curve From this point, passing into No. 3 Pit for a distance of about 100 yards, none of the timber, of which there was a large quantity, was blown out or displaced. At (21), about the centre of this undisturbed portion of road, blasting tools were observed standing upright against the side of the road, not having been blown over. The only sign of force on this length of road was a slight disturbance of one or two sheaves carrying a haulage rope near the roof, and of a wire rapper rope. The rapper rope was coiled round the haulage rope, and a few yards of it were drawn or shoved in a sort of knot against a sheave. As this was close to the undisturbed blasting gear it appeared probable that the force was transmitted by the ropes themselves when they were disturbed by falls of stone or timber at some point outside this length of road. After passing over this undisturbed portion of road the timber was again found blown out, and this displacement of timber continued up to the limits of the explosion in every direction; heavy falls of stone being caused in many places by its removal. At (22) is the road leading to No. 3 or the upcast pit; doors here were blown towards that shaft, and nearer the shaft tubs had been traversed by force passing to it. At the upcast shaft (23) the scaffold and wire rope guides were displaced, and doors beyond the shaft were blown to the return. Here also doors leading to No. 3 furnace were blown towards the furnace. At (24), on the other road off the main intake to No. 3 shaft, timber was blown towards the shaft; the doors which stood on this road had completely disappeared.

Returning to the main road at (22) doors were blown northward towards the North Main Coal. The explosion did not extend into the North Main Coal. On the main road at this point stood an engine, the pressure gauge pipe of which was bent towards the west. At (25) a wall was displaced westward. At (26) a large wheel was broken, and part of it carried to the west; the cleading or fencing of this wheel was blown in the same direction. The air crossing near here was displaced. At (27), to the east of the South way end, the sheet iron guard of a sheave was bent over to the east, and within the South way a similar guard was bent over to the south. At (28) was a staple, down which coal tubs were lowered from the Main Coal Seam; timber in the staple was displaced and doors near it were blown into the return. Passing along the South way at (29) tubs and sheaves had been traversed by force passing southward. At (30) two air crossings were displaced. The explosion ceased a short distance beyond the crossings. Returning to the road going west an abandoned way known as the West incline was examined. At (31) a loose coil of rapper rope was driven eastward on to a loose rail. At (32) bricks from a wall (built at side of road in order to make a definite area for measuring air) were blown eastward. Near (33) two rope rollers, partially torn from their framework, showed signs of force passing west. At (34) the incline wheel, seven feet in diameter, was torn from its framework and carried thirty yards westward. This wheel, with its brake attachments, would probably weigh half a ton. Further up this road five pairs of doors were blown to the returns. The explosion ceased a short distance from the face, and next the goaf a light wood fence was undisturbed.

Returning to the shafts:—from each end of the curve, roads passed through a dislocation, which threw the Hutton and Maudlin Seams nearly on one level; these roads joined on the Maudlin side of the trouble. One of them passing direct from the downcast shaft was known as the travelling way, and the other was the haulage road along which the coal from the Maudlin Seam passed to No. 3 Pit. On the travelling way at (35) bricks from an air measuring place were blown towards No. 1 Pit, and the air crossing further along it was displaced. On the other road, disturbance commenced at its junction with the curve (20), where timber was displaced. At (36) tail rope sheaves on spindles, fixed in the side of road, were blown in-bye, and the spindles bent in the same direction. Near the junction of the two roads, through the dislocation at (37), a travelling road and second intake, similar to that described as existing in No. 1 Pit, left the haulage road, rejoining it at (38). This travelling road, like the other, had not been traversed by the explosion, but was disturbed only for a short distance from each end. On the Maudlin haulage road, near the East way end (39), a chock built of timber placed crossways was moved inward. Near (40) a balk was observed slewed outward, the prop under one end of it was blown out, and it had moved on the other as a pivot. The explosion ceased in here about the engine landing (41). In the East way of the Maudlin it had passed almost to the face.

It will be observed that all the indications of the path of the explosion are on the main intake air ways and haulage roads. The return air ways and those parts of the intake and haulage roads not affected by the explosion were carefully examined, and no difficulty was found in coming to a positive conclusion that they had been traversed by neither force nor flame. In all cases, doors, air crossings, and such stoppings as were moved, were blown from the intakes to the returns.

The distinct evidences of flame having existed over the roads traversed by the explosion were few at Seaham, beyond the burning of men and horses, and fires found burning after the explosion. There was a marked absence of coked coal dust, but a microscopical and chemical examination of coal dust from roads traversed by the explosion, made by Sir F. (then Professor) Abel, afforded evidence of the action of flame upon it. Unfortunately, no exact record was kept as to the burning of the bodies of the victims, but so far as observations were made, it was found that the bodies of men and horses, who had been on the roads traversed by the explosion, were burnt, and as traces of fire were found on these roads, far apart, it is concluded that the flame had passed continuously along them.

In No. 1 Pit, the onsetter was burnt near the downcast shaft (1). At (2) the coal was found burning after the explosion. At (4) the engine house was on fire. At (12) a man was burnt. Between (17 and 18) timber was charred.

In No. 3 Pit, at (20) and (21) men were burnt. At (22) burnt coal or dust was observed. At (28) timber on fire was extinguished by survivors.

In the Maudlin, the stables on the east side of the road at (37) were on fire. Near (41) timber was charred. At (43) the stables in the East way had been the scene of a fire, smoke and steam were seen by the explorers before this part of the pit was sealed off, and on re-opening the mine it was found that there had been an extensive fire in these stables.

At the time of the explosion there were on the plane of the explosion 169 persons; five of these survived, one being the onsetter at the downcast shaft, and four workmen from the South way in No. 3 Pit, who escaped to the shaft by the return air road.

There were the following fires and naked lights on the plane of the explosion:—

Open lamps at the downcast shaft.
Open lamps at the upcast shaft.
No. 1 furnace and 2 boiler fires near it, fed with return air.
No. 3 furnace fed with return air.
No. 1 boilers fed with fresh air.

Four horsekeepers carried naked lights. One of them was found near the stables in No. 1 Pit, near (6). One in the stables in No. 3 Pit, near (22). Two were found in the Maudlin; one in the west stables, near (37); and the other on the haulage road of the East way, at (42).

Each of the workmen, except the four horsekeepers, had a safety lamp.

There was possibly an open lamp at the bottom of the Main Coal Staple (28). One hung there, but it was not known whether it was lighted at the time of the explosion.

Shots were to be fired on the night of the explosion at three points in No. 3 Pit. One, west of the curve, at (21); and two, near the South way end, (27). These shots were all to be fired for the purpose of enlarging refuge holes.

The workmen on the plane of the explosion may be divided into three classes:—First, the survivors; second, victims in the field of the explosion, or who had been traversed by force or flame, or both; third, victims outside the field of the explosion.

Of the survivors, one of them, the onsetter at the downcast shaft had been in the field of the explosion; the other four persons were outside the field. These men had been under no alarm up to the time of the explosion.

The workmen in those parts of the pit over which the force and flame of the explosion had extended, or victims in the field of the explosion, were all found at the places where their work required them, and there appeared no reason for supposing that any of them had been alarmed previous to the explosion.

Those of the workmen who had been outside the field of the explosion were found, in most cases with their lamps, at some distance from their working places, and they had perished by after-damp while coming out, or while waiting for rescue. There was evidence in the form of written records that some of these men had lived for some hours after the explosion.* The oil in some of their lamps was exhausted, showing that they had continued burning for some hours after the explosion.

In fixing the point of origin of this explosion, the first consideration which forcibly presented itself was, that this point did not lie at or near any of the working faces where the bulk of the workmen were, but at some place within a short distance of the shafts. Thus, in No. 1 Pit, the indications at (1), (4), (5), (9), (10), (13), (15), (16), and (17) showed that the explosion had gone inward from the downcast shaft. In No. 3 Pit, the indications at (22), (25), (26), (33), and (34) showed it had gone up the West incline from some point to the east of the road leading to No. 3 Pit; and indication (29), that it had passed into the South way from its junction with the West way. In the Maudlin, indications at (36) and (39), showed that force had gone inward from the junction of the Maudlin haulage road with the curve.

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* See Note A.

It will be observed that there were on each of the three long lines of road, certain minor indications, at (1) and (3) in No. 1 Pit; at (27), (31), and (32) in No. 3 Pit; and at (40) in the Maudlin, which pointed to force coming outward. It is somewhat difficult to account for these reverse indications, but it would appear that in some, if not in all cases, there is a reverse current of considerable force succeeding the explosion, sufficient in strength to move loose materials or bodies already disturbed by the original force; and the writers conclude that these outward indications were due to this secondary action, as in all cases much stronger indications of inward force were observed.

The positions in which the bodies of the men from all the working faces were found showed that they had been killed by after-damp, and not by the force or fire of the explosion.

As the indications clearly pointed to the vicinity of the shafts as the place where the explosion had originated, attention was naturally directed to the furnaces near (19) and (23), as the return air carrying off all the gas issuing from the plane of the explosion passed over these furnaces. In addition to this, there were, at Seaham, large goaves within a comparatively short distance of the shafts. The possibility of the explosion having had its origin at one of these furnaces was carefully considered. It was quite evident, however, that the explosion had passed from the intakes to the furnaces. In both cases, doors separating the intakes from the returns near the furnaces were blown towards the furnaces, and in all other cases, doors, regulators, air crossings, and stoppings were blown from the intakes to the returns. In the return air ways there was satisfactory evidence that no explosion had passed to or from the furnaces by that route. In both cases the caution boards, about 50 yards from the furnaces, were unmoved, and a miniature wind-mill near one of them was not blown down. At no point was any disturbance observed in the return air ways, except at points where the explosion had blown into them from the intakes. The considerations applying to the furnaces apply equally to the boiler fires fed with return air near No. 1 furnace. The regulating doors leading to the No. 1 Pit boilers, fed with fresh air, at (2), were blown towards the boilers, and this, with other evidence, negatived the idea that the explosion had originated at them.

There was nothing whatever to show that the naked lights at the shafts or the open lights or lanterns carried by the four horsekeepers could be selected as a point of origin.

The workmen in No. 3 Pit, to the west of the road leading from the intake (22) to the upcast shaft, had been traversed by the explosion, passing into the West and South ways. Two shots had been fired near (27), between the air crossing and the South way end, but apparently some time before the explosion.

There remain now for consideration two men working on the undisturbed portion of the main road to the west of the curve. From the position in which these men were found, and from facts observed at the point where they were engaged, it was evident that they had fired a shot in the stone either immediately before or simultaneously with the explosion, near the centre of the undisturbed portion of road. The road here was in stone, and these men had been engaged in enlarging a refuge hole by blasting. Part of the end of the drill hole was visible, and the stone blown down by the shot had not been removed. The blasting gear was standing near, set upright against the side. A broom was observed near the place.* One of the stonemen was found in a refuge hole 20 yards to the west of the shot, and the other was 40 yards to the east, these being positions they might naturally assume after lighting a shot. These men had safety lamps. In lighting a shot they did not unscrew the lamp top off, but inserted a thin pliant wire through the gauze into the flame, withdrawing it quickly when heated and applying it to touch-paper; this touch-paper took fire and in turn ignited powder in a straw in the pricker hole of the shot.

The writers assume an issue of flame from the shot as the ignition point of the explosion.

The indications of force strongly point to the undisturbed section of the main road as being the starting point of the explosion, force radiating from here in three directions.

It was ascertained that the explosion, in passing from the Maudlin and No. 1 Pit into No. 3 Pit, or *vice versa*, must have traversed this undisturbed length; the only other routes available were examined, and it was clear no explosion had passed along them. If, therefore, the point of origin lay outside this length of road, the difficulty presented itself of accounting for the absence of disturbance on it; no other examples of force dying out for 100 yards and resuming again its full strength were observed.

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* Supposed to have been used for sweeping away dust before firing a shot.

If, however, the explosion originated in the undisturbed length of road it did not appear unreasonable to suppose that in some way the force increased in each direction, and this is what the writers assume took place. It will be observed that the existence of flame is proved in the undisturbed length of road.

The next factor to be considered is the explosive material. The only substances which have ever been regarded as contributory to colliery explosions are fire-damp and coal dust, and until recently the influence of the latter was practically ignored. The explosive nature of mixtures of fire-damp and air is well known, but in attempting to account for this explosion, on the assumption that it was caused by fire-damp, there are difficulties which appear to the writers to be insurmountable. These difficulties, moreover, are independent of the precise position of the point of ignition, and would apply with equal force to any point selected. The chief difficulty is to account for the extension of the explosion for long distances over the main intake air ways; roads constantly swept by large volumes of air, separating into three main currents at the downcast shaft. It is incredible that the air on all these roads was in an inflammable or explosive state, due to the presence of fire-damp. The absence of alarm amongst the workmen on them, at the time of the explosion, goes far to prove that it was not. To account for the air passing along any one of the intakes, being charged with fire-damp, it is necessary to assume a sudden discharge of gas at some point, of which there was no evidence whatever. All these roads were old and spacious galleries, along which large currents of air passed direct from the downcast shaft, and the tendency of the air was to pass from them into all side openings. Naked lights were used on them daily, and at the time of the explosion some such lights were in use on them.

It was very improbable that there had been any accumulation of fire-damp in any place out of the direct current of air, and any possible accumulation of the kind must necessarily have been too small in amount to account for the effects observed.

Apart, however, from the difficulty of accounting for the presence of fire-damp at any possible point of ignition, greater difficulties present themselves in attempting to account for the large extent of the explosion, and the fact that it had been confined to one particular class of roads: the haulage roads. Indeed, a consideration of these phenomena appears to negative the possibility of any gaseous body having carried the explosion over the mine.

Had the explosion been due to the combustion of fire-damp, existing either as a fouled air current, or as an accumulation or series of accumulations, it is evident that in exploding it would extend indifferently over all the open roads accessible to it (other than that on which it existed) until the expansion ceased. This was not the case, but the contrary. On each of the three long lines of road, over which the explosion extended, it missed certain portions along which passed air split off the same current. These portions of intake air roads, all well within the field of the explosion over which it did not pass, were the travelling roads in No. 1 Pit, and the Maudlin, the North Main Coal, and the South way in No. 3 Pit. Neither had the explosion traversed any of the return air ways, along which pass all the fire-damp given off in the mine.

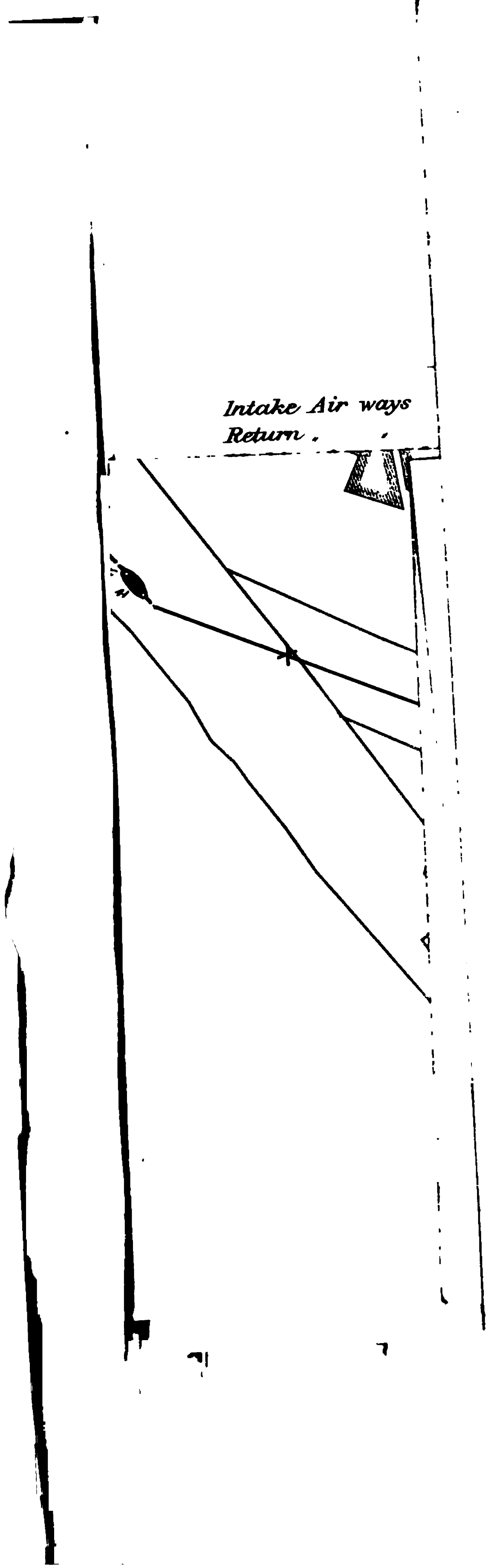
The apparent impossibility of accounting for the effects of this explosion, on the assumption that it was due to fire-damp and air, and the great difficulty in accounting for the presence of any fire-damp at any point at which the explosion could possibly have had its origin, directed attention to coal dust. There was coal dust on all the roads traversed by the explosion, and there was coal dust at the supposed point of origin. Seaham is a very dry colliery, and the haulage roads were the driest parts of it. The coal dust in the vicinity of the downcast shaft proceeded in part from the surface, being carried in the air from the screens and deposited in the pit; on a sunny day the particles of dust could be seen glistening in the air, and going down the shaft. The chief source of the dust on the haulage roads was from the tubs of coal, drawn by engine power at the rate of 10 or 12 miles an hour, against currents of air moving in the opposite direction. The coal being dry and dusty, much dust was swept off the tubs and settled on the roads, and beyond what was thus swept off, both dust and small coal were shaken out of any holes there were in the tubs.

The return air roads were practically free from coal dust, no coal was led along these roads, and the chief source of coal dust was therefore absent. After the driving of these roads in the coal, a considerable amount of work was done in them from time to time in the shape of forming stone pillars, removing fallen stone, etc., and they were constantly travelled by the wastemen and officials. They were dry, and these operations produced a quantity of stone dust, grey in colour. No coal was led along the travelling roads in No. 1 Pit and in the Maudlin; they were used as doubling the intake air road, and as travelling roads for men and horses; the dust in them was principally stone dust. The inner portion of the South way in No. 3 Pit, beyond the point to which the explosion extended, was a horse road, and the dust on it was largely mixed with stone dust, caused by the grinding of the soft bottom stone by the feet of men and horses. The coal being led by horses did not travel at a high speed, and the current of air passing along this road had no great velocity. The North Main Coal, into which the explosion did not extend, was damp and free from coal dust.

It thus appears, that on all the roads traversed by the explosion there was a plentiful supply of coal dust, while those portions of the roads which it had apparently so capriciously missed were, in comparison, free from coal dust. In the absence of any other means of accounting for the extent and course of the explosion, these facts are of striking significance. After the explosion all the parts of the mine, in which its effects could be traced, were covered on the bottom and on flat surfaces with a coating of fine dust, impalpable and almost like soot, which when examined under the microscope appeared to have been acted on by great heat. This fine dust covered the surfaces for a depth of from ⅛ to ½ an inch, and under it, on the roadways, was coarser dust and refuse. Dust of this nature was entirely absent on those roads over which the explosion had not extended.

There was a marked absence of the coked or charred dust so often found after explosions, but that part of the volatile matter was expelled from the dust, was proved by the analyses of Sir Frederick Abel, undertaken at the request of the Miners' National Association. It would be difficult to estimate whether a sufficient amount of volatile inflammable matter had been expelled to consume all the oxygen in the air on the roads over which the explosion passed, but it would only require a small proportion of the total amount of such volatile matter to do so.

It will be observed that the explosion had been arrested at a considerable distance from the face in the Third East way in No. 1 Pit, and the West way in the Maudlin. The reason of this was not quite obvious, but it may have arisen either from the action of heavy falls or from the failure of the supply of dust. In the Third East way of No. 1 Pit, there was a small feeder of water near the place where the explosion ceased, issuing from the bottom and running to a pump further in, and so causing the road to be damp. This was about 300 yards beyond where the road was completely closed by the fall of the arching; this fall would close the road as soon as the arch was lifted, and if this took place before the flame had passed the point it would prevent its passage. This, however, is conjectural, and it is perhaps more probable that the arrest of the explosion was due to the lack of dust. In the case of the West way in the Maudlin, there is some probability that the road was damp at the place where the explosion stopped, because water was


Intake Air ways
Return ,,

led over it from a stone drift in the vicinity. The state of the road here had not been particularly observed before the Maudlin Seam was shut off on account of the fire.

It is necessary to account for the ignition of the dust. At the place, which is concluded to have been the point of origin, a shot had been fired, apparently simultaneously with the explosion. The shot hole had been drilled at right angles to the line of road, the outer end pointing slightly upward. The road at the place was in stone, and would probably be coated with the finest coal dust, and just above the shot, were large balks of timber set about 9 inches from the roof on which lodged much dust. It was not a blown out shot; the stone it was intended to dislodge being thrown. It does not follow from this that it would show no flame; many properly prepared shots show flame when they do their work, and if there is an overcharge of powder, or coal dust in the stemming, the flame is greater. The shock caused by the explosion of the shot would dislodge the dust and throw it into the air, and flame issuing, not necessarily to a large extent, would ignite it and fill the road with flame. Thus initiated the flame would extend along all the roads on which there was an uninterrupted supply of coal dust to support it.

TRIMDON GRANGE COLLIERY EXPLOSION.

On the 16th February, 1882, at about 2·30 p.m., an explosion took place at Trimdon Grange Colliery, in the County of Durham. It caused the death of 68 men and boys and 11 horses and ponies in that colliery, and the death of 6 persons in the workings of the East Hetton Colliery adjoining. Two of the latter—Mr. H. C. Schier, manager, and T. Blenkinsopp, master wasteman—descended after the explosion, and were killed by after-damp while endeavouring to rescue the workmen.

The explosion was entirely confined to workings in the Harvey Seam, on one plane, which, at the shafts, lay at a depth of 286 yards.

The Low Main Seam was being worked at a depth of 194 yards, but was unaffected by the explosion.

The downcast shaft, 12 feet in diameter, was sunk a few yards below the Harvey Seam, and coal was raised from it up this shaft by two cages running in wire rope guides. This shaft was wet. The upcast shaft lay 40 yards to the east of the downcast, and was sunk to the Low Main Seam only; it was 13 feet 9 inches diameter. A staple, 10 feet in diameter and 92 yards deep, sunk from the Low Main to the Harvey Seam, near the upcast shaft, was the upcast from the Harvey Seam workings.

The general inclination of the Harvey Seam was to the N.E., the dip in that direction being about 2 inches to the yard.

From the downcast shaft haulage roads extended to the north and south. The explosion did not affect the districts to the south of the shaft. To the west of the haulage road passing northward, were three principal districts—the Headways, the Cross-cut, and the Pit Narrow Board districts.

The haulage from the landings (shown on plans) was effected by an engine near the shafts working main and tail ropes.

The ventilation of the colliery was caused by a furnace in the Harvey Seam at the bottom of the upcast staple. This furnace was fed with return air from the plane of the explosion. A furnaceman was in attendance at the time of the explosion, and there was no reason to suppose that the fires were not in their ordinary state.

The quantity of air circulating in the Harvey Seam amounted, when measured eight days before the explosion, to 52,694 cubic feet per minute. It was distributed as follows :—

South side of shaft			**16,380**
Engine and boiler at shaft			**4,250**
Pit Narrow Board—			
Engine landing	**Estimated**	**1,000**	
Scale on First South doors	**do.**	**1,000**	
„ **Second** „	**do.**	**1,000**	
„ **Third** „	**do.**	**1,000**	
Reaching air way past Third South		**8,560**	
			12,560
Cross-cut			**8,533**
Headways—			
Passing to north		**2,000**	
To East Hetton		**1,000**	
Headways workings		**7,971**	
			10,971
			52,694

The lengths of the intakes and return were :—

	Intake. Yards.	Return. Yards.
Pit Narrow Board	1,757	1,716
Cross-cut	994	1,232
Headways	1,045	1,320

The sectional area of the intakes was about 48 square feet, and of the returns about 36 square feet.

The explosion took place during full work ; the working faces were occupied by hewers, and all the persons ordinarily employed in the leading of the coal to the shaft were in the mine.

About 400 tons of coal per day were raised from the Harvey Seam.

The Harvey Seam here is 3 feet 8 inches thick.

The Davy safety lamp was used by those workmen employed on the in-byeside of the caution boards.

Powder was used in the coal on the day of the explosion, and generally it was so used to a limited extent, and also for stone work.

The Harvey Seam at Trimdon Grange was moderately fiery. Near some points at the goaf edges gas was seen regularly; but these points were in the return air ways.

The coal was dry and dusty, and the roadways were dry, except at some points.

The barometer was low at the time of the explosion, and the minimum temperature was below freezing point some time during the day of the explosion. The following observations were taken at the colliery some time during the morning of the 15th and 16th:—

	Barometer.	Thermometer.		Barometer.	Thermometer.
Feb. 15th, surface ...	29·30	41° F.	Underground ...	30·10	51° F.
„ 16th „ ...	29·10	35° F.	„ ...	30·10	50° F.

At Durham University Observatory, on February 16th, the maximum temperature was 52·8 deg. F., and the minimum 29·0 deg. F.

The workmen had not made a complete examination of the Harvey Seam for a year and a half before the explosion. A special examination of the Headways district was made on the 24th of August, 1881, after some of the workmen had seen some gas near the goaf. When this examination was made no gas was found.

The officials of the colliery, from their examination of the mine on the day preceding, and on the day of the explosion, had discovered no unusual source of danger.

The damage done to the downcast shaft being small (partly owing to the absence of timber in it, wire rope guides being used) and no fires being caused by the explosion, the exploration of the workings, and recovery of the bodies of the victims, was rapidly effected; no special difficulties were encountered. The last body was brought out within three days of the explosion.

It was found that the explosion had extended to the downcast shaft, and to the working face in the Pit Narrow Board and Headways districts.

The most distant parts affected by the explosion were 2,800 yards apart by the route traversed by the explosion; this route being along the main intake and haulage roads. No damage was done in the return air ways, except at points where doors, stoppings, or air crossways were blown into them from the intakes. Near the face of the workings and in the return air ways adjacent, at both extremities, there was coked coal dust on the timber. On the intake air roads, where the greatest damage was done, no coked dust was observed, but men and horses who had been on these roads at the time of the explosion were all burnt.

The timber at the bottom of the downcast shaft (1) was blown out, and the wire rope guides disarranged. Near the shaft two pairs of separation doors were blown from the intake to the upcast staple and furnace. Some force had passed over the furnace, blowing the bridge to the staple.

On the south side of the shaft some force had been exerted, but this exhibition of force did not extend far, and was due to the explosion on the north side.

The roof stone at Trimdon Grange was generally good, and fewer falls of stone were observed than otherwise would have been the case.

Passing from the downcast shaft down the Pit Narrow Board or main intake and haulage road, it was observed that the timber was all displaced. Three air crossings were destroyed, being blown from the intake to the return, and three pairs of doors were blown in the same direction; but no indication of direction of force along the main road itself was seen until the engine landing (2) was reached. Here, about 20 yards south of the landing, there were some indications of force out-bye, or to the south; some light articles, including "bait tins," or provision cases, were found nearer the shaft than the place where they were usually kept. Here also a rapper lever was found 11 yards nearer the shaft than the place where it had been fixed; this might, however, have been caused by some weight falling on the wire further out.

A set of full tubs stood within the landing. The tub nearest the shaft was broken, as if by force passing northward, the top only was broken; the coal was piled up, and the corner pieces forced northward.

At the First South way end (3) part of the door frame, one of the door bands, and bricks from the door setting, were blown towards the face. The trapper boy who attended the door was found nearer the face than where the door had stood; he was enveloped in a canvas sheet, which hung on the in-byeside of the wood door, as if he had been blown into it.

A few bricks were found as though they had been blown outward from the door, and opposite the way end, some *débris*, consisting of dust and pieces of wood and coal, was blown against the side of the way, or northward. At (4), in the First South way, the clothing of the putters was found 30 yards nearer the face than the place where they were in the habit of leaving it on commencing work. The stoppings on each side of the First South way were blown to right and left.

At the Second South way end (5) the door stanchions, and one of the door bands, were observed 20 yards nearer the face than where the door had stood. Tools and nails, which had been in a chest standing on the out-byeside of the door, were found scattered in the direction of the face, or in-bye. Here, as at the First South way end, there also appeared to have been some force outward, the remains of the chest, with other *débris*, were blown against the wall side, opposite the way end. At (6), on the Second South haulage road, putters' clothing was found 14 yards nearer the face than the place where they were in the habit of leaving it. The stoppings on each side of this road were blown to right and left.

The main haulage road between the Second and Third South ways was undisturbed; the timber was standing, and a driver with a horse and set of tubs on this part of the road were uninjured and unburnt. The horse and driver had been killed by after-damp.

At the Third South way end (7) the door was shattered, but not displaced; some bricks from the door setting and part of the door frame were blown outward. The explosion did not appear to have traversed the Third South haulage road. No damage was observed, except that the stoppings on each side of the road had been blown out, and they were not blown to right and left as in the First and Second South ways, but all to the right or north-west.

From the engine landing at (2) the stoppings, as far as the Second South way end (5), were all forced or blown inward, that is, from the intake; those which were not stowed were found scattered along towards the return, as shown by arrows. On the in-byeside of the Second South way end the stoppings were blown outward on to the main road.

Along the working face of the First, Second, and Third South ways the force, as established by observations made on tubs, etc., had passed in the direction shown by arrows at (8) (8), etc.

Returning to the junction of the Headways and Cross-cut haulage road with the Pit Narrow Board, and passing along the former, it was observed that the first two stoppings on the right side of the road were blown on to the road (9). At (10), a bell sheave for guiding the haulage rope was observed forced in-bye. At the junction of the Headways and Cross-cut haulage roads a wagonwayman's chest and tools were blown in-bye (11).

Beyond the junction in the Cross-cut haulage road, the first two stoppings on each side and a pair of doors were blown to the return, as shown by arrows, but no further disturbance was observed on this road. No timber was displaced, and no explosion had passed along it.

Proceeding into the Headways way, it was observed that doors and stoppings were blown to the returns. At the shaft end of the engine-landing at (12), tubs had been traversed by force going in-bye. At the other end a metal cistern was broken, and part of it carried in-bye. Further in, at the pillar workings (13), a deputy's chest was blown 20 yards in-bye, and at (14) tubs and doors were blown in-bye. At (15), doors in a passage between Trimdon Grange and East Hetton Collieries were blown out in the direction of the latter colliery, leading to the death of six men in its workings by after-damp.

The return air ways at Trimdon Grange were examined, and it was clear no explosion had traversed them, except for a short distance from the working face.

The following indications of fire were observed:—

Near the downcast shaft (1) a man was burnt. At the junction of the Pit Narrow Board and Cross-cut ways a man was burnt. On the Pit Narrow Board haulage road, 210 yards from the landing, a boy was burnt, and at that landing (2) another boy was burnt. The trapper boys at the First and Second South way ends (3) and (5) were burnt. The men at the face of the First, Second, and Third South ways were in most cases burnt, and coked coal dust was observed along the whole length of the working face and in the return air way adjacent, adhering to the timber. Coked dust was also observed in the unused passages of this part of the pit, so far as they could be examined. At the junction of the Cross-cut and Headways way (11) a man was burnt. At the landing in the Headways way (12) boys and horses were burnt. At the pillar workings, further in (13) and (14), men were burnt. A man and a pony were burnt in the narrow boards going south from the Headways way (16), and coked coal dust was observed at the working face and in the return air way adjacent.

No coked dust was observed on the main haulage roads, where flame had evidently passed, and where force had been greatest. At the extremities of the explosion coked dust was abundant, and the force exerted less.

No fires were caused in the mine by this explosion.

At the time of the explosion there were on the plane of the explosion 94 persons, and there were consequently a number who survived. All the workmen on the south side of the shaft escaped, and most of those from the Cross-cut district. Neither of these districts was affected by the explosion, but the road to the shaft from the Cross-cut district lay partly in the affected portion, and this led to the death of six of the Cross-cut workmen by after-damp. Two others were found insensible by the explorers. An engineman, about 40 yards south of the shaft, had just started his engine when the effect of the explosion on the other side of the shaft reached him, He was injured and rendered insensible, but was not burnt.

There were the following fires on the plane of the explosion:—

Furnace for ventilation.

Boiler fire near the shaft.

There were also open lights at the downcast shaft.

The workmen on the in-byeside of the caution boards had each a Davy safety lamp. Naked lights were used up to the caution boards on the main roads. Drivers, whose work lay on each side of the caution boards, used safety lamps. Those workmen who were employed altogether on the out-byeside of the caution boards used naked lights. Beyond this no positive evidence was adduced as to the description of lights used by the workmen. It was known that some of the boys used "midgies," or open lights, on the out-byeside of the caution boards, and that two wagonwaymen used oil lamps.

Gunpowder had been used in the coal in the South ways on the day of the explosion, and a shot was ready for firing in the Headways way.

Dividing the workmen on the plane of the explosion, as at Seaham, there are—

1st.—The survivors.

2nd.—Victims in the field of the explosion.

3rd.—Victims outside the field of the explosion.

The survivors, comprising the men on the south side of the shaft, and those of the Cross-cut workmen who escaped to the shafts, all stated that they had been under no alarm up to the moment of the explosion.

The victims in the field of the explosion appeared, so far as a judgment could be made, to have been under no alarm up to within a few moments of their death. The four men who worked at the bottom of the downcast shaft were found dead there. The furnaceman was found near the shaft alive, but he died in a few days. An offtake lad and a wagonwayman were found at the junction of the Pit Narrow Board and Cross-cut haulage roads, where their work required them. On the Pit Narrow Board engine plane, 210 yards above the horse level, a driver was found. The empty tubs ran by gravitation to this point, bringing the rope with them. A driver met the set here, and pulled it with the rope into the landing with his horse. This driver was where his work required him. A lad was found near the landing (2). He was employed in driving a horse working a pump. He was within a few yards of his place of work. At the in-byeside of the doors, on the First South way, a trapper boy was found, apparently having been blown a short distance from his place of work. At the Second South way end a trapper boy was found on the horse level near his door. Between the Second and Third South ways, on the main road, a driver was found near his horse and tubs. The workmen and boys, 33 in number, at or near the face of work in the First, Second, and Third South ways were, in most instances, found at their working places. A few had moved a short distance, leaving their lamps, the most noticeable of whom were three hewers found on the Second South way near the face. At the junction of the Headways and Cross-cut haulage roads (11) an offtake lad was found at his place of work. At the landing in the Headways way (12) two drivers were found, where they might have been in the ordinary course of their work. At the first pillar workings, to the left of the Headways haulage road (13), five men had moved 30 or 40 yards from their working places; and at the second pillar workings (14), three men were found at their places of work. Six men were found at the face of the narrow boards, off the Headways way (16), at or near their working places.

The victims outside the field of the explosion were six men from the Cross-cut way, who perished from after-damp near the junction of the Cross-cut and Headways way while on their road to the shaft. They had moved out nearly half-a-mile. Four persons in an adjoining colliery, and two officials attempting their rescue, lost their lives by after-damp coming through a passage connecting the two mines.

The conclusion drawn from the indications left by the explosion is, that it began in the Pit Narrow Board district, and went into the Headways district. Thus, the first two stoppings on the right hand side of the Cross-cut way (9) could not have been blown on to the haulage road, except by a force coming up the Pit Narrow Board; and indications at (10), (11), (12), and (13), showed that force had gone into the Headways way.

As to the exact place in the Pit Narrow Board district at which the explosion began, the evidence is somewhat conflicting. At both the First and Second South way ends (3) and (5), there were signs that some force had come outward, and near the face of the Second South way, three of the hewers had run a short distance out of the working places, leaving their lamps, from which it might be inferred they had observed some danger. No unusual fall or disturbance was observed along the goaf edge, where they were working, and all the officials were positive in stating, that prior to the explosion, no gas had ever been seen in that district. If the explosion began here it must have been by gas firing at one of the safety lamps.

On the other hand, the doors at the First and Second South way ends (3) and (5), had been blown inward towards the face, and all the stoppings in a line with them, from the Pit Narrow Board landing (2) to the Second South way end (5), (except those which were rendered immovable by stowing), were also blown southward or towards the return and working face. The putters' clothing in the First and Second South ways, at (4) and (6), was also blown towards the face. This inclines the writers to the opinion that the explosion began on the out-byeside of these doors and stoppings.

This limits the part of the mine to be considered to the main intake and haulage road lying between the Second South way end, and a point some distance in-bye of the junction of the Cross-cut way with the Pit Narrow Board. On this portion of road there were the two trappers at the First and Second South way ends, the pump driver at the landing, and the driver, 210 yards nearer the shaft, waiting for the engine set.

The two trappers had Davy safety lamps, and these lamps were tested with others after the explosion and found to be perfect. One of the trappers had apparently been traversed by great force and blown towards the face. There did not appear to be any good reason for selecting either of these lamps as the point of origin.

It was not proved what description of light the driver at the pump or the driver meeting the engine set carried. They both worked on the out-byeside of the caution boards.

The indications near the landing (2) appeared to show that force had passed towards the shaft from here. The driver meeting the engine set had been traversed by considerable force, and was mutilated. There was nothing to suggest that the explosion had began at his light.

The Pit Narrow Board engine-landing was on the continuation of the road from the shaft, just beyond the horse level, passing to the left. Beyond the landing were some drowned workings lying to the dip of it. The current of air, ventilating the three South ways in this district, did not enter the landing, but passed along the horse level. The landing had been ventilated by a scale of air, which, after passing the landing, divided and passed through holes in the stoppings in the passages immediately below, and on each side of it; passing over the top of the water in both cases.

A horse pump was placed in a recess on the left side of the landing, and was used to pump the water out of the drowned workings, forcing it through pipes in the direction of the shaft. If the water was not pumped it rose on to the haulage roads. At the time of the explosion this pump was in use.

The writers think it probable that gas had risen into the landing from the drowned workings and ignited at the pump boy's light. The barometer was unusually low (29·10), which is a condition favourable to the movement of gas out of such places as these drowned workings. The lowering of the water by the pump may have liberated gas pent up in some part of them, and the issue may have overpowered the feeble current in the landing. After the explosion, and when the ventilation was restored, gas was found in the return air road, just above these drowned workings, and it could be heard bubbling through the water in them.

The mere statement that the explosion began either at this landing, or at the face of the Pit Narrow Board workings, is in no way sufficient to account for the results which ensued. When it is considered that the explosion extended with force and flame to parts of the pit more than a mile distant from either point, and that in doing so it had been confined to the main intake air ways, it appears impossible to attribute its extension to an accumulation or sudden outburst of gas at either place.

The state of the return air roads clearly proved that no blast had traversed them, except for a short distance from the working face, where the dust in them was principally coal dust, and where coked coal dust was observed after the explosion; while on the intake air roads men and horses at different points were burnt, timber was blown out, tubs broken, and doors, air crossings, and stoppings, were blown from the intakes towards the returns.

The writers suppose the wave, or movement of air accompanying the ignition of a mixture of fire-damp and air in the landing, had raised a cloud of coal dust, and that the flame from the fire-damp had passed into this cloud, causing ignition of the coal dust; the ignition of the coal dust thus started became self-propagating, and continued with force and flame over those parts of the pit where a sufficient quantity of coal dust existed.

A remarkable circumstance in this explosion was, that it did not extend into the Cross-cut way, and the writers can only account for this by stating that this road was damp, and consequently free from coal dust, for some distance from its junction with the Headways way. There were

two sumps for collecting the water which accumulated on it, one 50 and the other 80 yards from the junction; the way was raised a little and ballasted with cinders which were moist. It will be seen from the plans that the direct course for the blast on leaving the Pit Narrow Board was into this way, and the air which passed along it was part of the same current as went into the Headways way. This appears to show that the air going into neither way could have been in an explosive condition, and the only fact which appears to account for the blast being deflected into the Headways way was, that there it found a sufficiency of fuel in the shape of coal dust, while in the Cross-cut way, this fuel was lacking.

Another wet portion of road, the Third South in the Pit Narrow Board way, had not been traversed by the explosion.

The explosion did not extend past the shaft into the workings beyond. The shaft was wet, and consequently the roads for some distance on each side of it were damp and free from dust.

TUDHOE COLLIERY EXPLOSION.

On the 18th April, 1882, at about 1·15 a.m., an explosion resulting in the loss of 37 lives took place at Tudhoe Colliery, in the County of Durham. Seventy horses and ponies were also killed. One person who descended after the explosion lost his life by after-damp.

The explosion was entirely confined to workings in the Brockwell Seam, on one plane, which lies at the shafts, at a depth of 174 yards. At a depth of 90 yards the Hutton, and at a depth of 134 yards the Busty Seams, were being worked from the same shafts, but these workings were not affected by the explosion, nor were any lives lost in them.

Three shafts were sunk to the Brockwell Seam. The East Pit, 12½ feet diameter, was a downcast shaft, and coal from the plane of the explosion was raised up it. The West Pit, 12½ feet diameter, was also a downcast shaft, and coal from the plane of the explosion was raised up it. These shafts were 58 yards apart. The Success Pit, 13 feet diameter, and situated 180 yards from the downcast shafts, was upcast for the whole colliery, and was used for no other purpose. The downcast shafts were wet.

The general inclination of the Brockwell Seam was to the N. E., dipping in that direction at the rate of about one inch per yard.

From the East Pit a haulage road extended in each direction to the north and south. That to the south was not affected by the explosion. To the right of the road, passing to the north from the East Pit, were three main branch roads, called the Shieldfield, Croxdale, and Coldstream ways. From the West Pit a haulage road, with several branches, extended in a westerly direction. Two engines near the pits, supplied with steam from the surface, hauled the coal from the various landings by means of main and tail ropes.

The ventilation of the whole colliery was caused by a Guibal fan, 40 feet in diameter, and 12 feet wide. It stood at the top of the upcast shaft and exhausted the air. The quantity of air passing through the mine amounted to 174,600 cubic feet per minute; of this quantity 85,000 cubic feet was from the Brockwell. It was distributed as follows:—

EAST PIT—Sunderland Bridge way—				
	Shieldfield	13,275		
	Sunderland Bridge, Croxdale and Coldstream	9,074		
	Scales	1,549		
			23,898	
	South side of the shaft—			
	Ferryhill and No. 5	6,237		
	Team Valley	19,404		
	Scales	2,536		
			28,177	
				52,075
WEST PIT—				
	Alma Bank	9,875		
	No. 5	5,852		
	No. 6	13,473		
	Scales	3,728		
			32,928	
				32,928
	Total			85,003

The main intake and haulage road of the East Pit extended north for a distance of 2,035 yards, and that of the West Pit 2,024 yards to the west. These, with branch intake and haulage roads, return air ways, and working faces, made up a total length of roadways in use in the district of the explosion of more than 22,000 yards.

The sectional area of the East Pit main intake was 42 square feet, and of the West Pit main intake 49 square feet. The branch intakes were smaller in sectional area.

The return air ways varied in sectional area from 21 to 31½ square feet. The whole of the air from any district was seldom confined to one return air road.

The greater part of the working faces were occupied by three shifts of hewers, the last or night shift returning to the surface about midnight.

It was during the interval between the night shift and early morning, or fore shift of hewers, that the explosion took place. The men in the pit at the time of the explosion were chiefly repairers and stonemen.

More than 1,000 tons of coal per day were raised from the plane of the explosion.

The Brockwell Seam is 3 feet 6 inches thick at Tudhoe Colliery.

The Davy safety lamp was principally used, but some Clanny and Stephenson lamps were in use.

Gunpowder was used in the coal in the whole or first working, but not in the pillar workings. It was used in stone work also.

The Brockwell Seam at Tudhoe did not produce much gas. Firedamp was seen occasionally near the goaf edge.

The coal was generally dry and dusty, and the greater part of the engine haulage roads were dry.

The workmen of the colliery had, under the 30th General Rule of the Coal Mines Act, examined the districts affected by the explosion on April 6th, 7th, 11th, 12th, and 13th, and their report was satisfactory.

The officials of the colliery knew of no unusual source of danger. Within two hours of the explosion a shift of deputy overmen had come out of the pit from the various districts, and they stated that everything was in its usual state when they left the pit. The master-shifter, the officer in charge of the pit at the time of the explosion, survived, and stated that his examinations of the mine had revealed nothing to lead him to suspect an explosion possible.

Entry was soon effected into the mine after the explosion by the East Pit shaft, which was not much damaged. No fires had been caused by the explosion, and no unusual difficulties were encountered. The pit was rapidly explored, and the last body was brought to the surface four days after that on which the explosion occurred.

It was found that the explosion had reached the downcast shafts and the engine-landings in the Sunderland Bridge way of the East Pit, and in the West way of the West Pit, and had extended for some distance into all the branch ways. The landings mentioned are about 2,500 yards apart by the route traversed by the explosion—that is, along the main intake air ways.

The circumstances of this explosion were not so fully investigated by the writers as those in the other cases were. The explosion at West Stanley occurred the night after that at Tudhoe, and diverted attention from the explorations at the latter place. From this and other reasons the indications observed were comparatively few.

(1) Considerable damage was done to the timber in the East and West Pit shafts. Passing from the East Pit along the Sunderland Bridge haulage road, at the junction of the travelling way to the West Pit (2), a brick wall was blown southward. The timber on the Sunderland Bridge road was displaced from the East Pit as far as the second air crossing (3). Beyond this point, up to the Shieldfield way end, the timber was not disturbed. Here the disturbance recommenced and continued up to the landing in the Sunderland Bridge way. Within the Shieldfield haulage road a chest, at (4), was blown in-bye, and, at (5), tubs had been traversed by force passing in-bye. The air vessel of a pump had been forced in-bye near these tubs. The explosion ceased at the landing in the Shieldfield way. It had passed up the Croxdale and Coldstream haulage roads some distance.

Returning to the shafts, and starting from the West Pit, the stalls in a stable on the right side of the road, at (6), had been blown northward. The explosion appeared to have passed between the East and West Pit workings by a short travelling road connecting the haulage roads near the shafts. In the West Pit, the disturbance, such as displacement of timbering, causing heavy falls of roof, and the blowing out of doors and stoppings, continued up to the limits shown by broken lines on Plan 2. At the West way landing (7), the return wheel of the haulage rope was forced in-bye out of its bearings. A door beyond the landing was blown in-bye. The explosion had not extended far along old No. 5 way. At the junction of No. 6 and new No. 5 haulage roads a balk supporting brickwork, at an unused air crossing, was forced in-bye (8). In new No. 5 way, at (9), large timbers were blown in-bye. At (10) the chain attaching the main rope to a set of tubs was broken. The tubs were being drawn in-bye by the tail rope at the time of the explosion, the main rope drum running loose on its shaft. It is possible that the breaking of this chain was caused by falls of stone on the rope further out. At (11), in the whin dyke, a sheet of thin iron plate, placed near the roof to protect persons passing along from water issuing from the roof, was observed to have been blown 21 yards in the direction of the shaft. This was near the limit of the explosion in this direction, and was clearly caused by a reversed current. There was no one in the workings beyond it. All the doors, air crossings, and such stoppings as were moved, were blown from the intakes to the returns. No disturbance was observed in the return air ways.

Indications of the presence of flame were almost entirely confined to the bodies of the victims of the explosion.

Thus men were burnt near the downcast shafts. Men were also burnt at the following places:—In the East Pit; near the Shieldfield way end, near the Croxdale way end, near the Coldstream way end, and between there and the Sunderland Bridge way landing: in the West Pit; near No. 6 way end, near No. 5 way end, and in No. 6 way, the men in the engine set were burnt at (10).

The explosion caused no fires in the mine.

At the time of the explosion there were, on the plane of the explosion, some 60 or 70 men. All to the south of the pits survived, and a few men were rescued from the neighbourhood of the shafts, some of whom afterwards died.

There was a fire at a boiler on the plane of the explosion, about 1,000 yards from the shafts to the south, and not in the field of the explosion.

All the workmen on the in-byeside of the caution boards had safety lamps; some of those on the out-byeside of the caution boards had safety lamps and some open lights. There were open lights about the shafts, and the workmen who, at the time of the explosion, were being drawn in-bye in a set of tubs, at (10), had naked lights with them.

Gunpowder was to be used at two points on the night of the explosion; one of these points was on the main intake, between the shaft and the Shieldfield way end. Two men here were blasting down stone in order to enlarge a stenton, or passage, between the intake and return air ways.

Classifying the workmen on the plane of the explosion as before, we have:—

1st.—Survivors.
2nd.—Victims in the field of the explosion.
3rd.—Victims outside the field of the explosion.

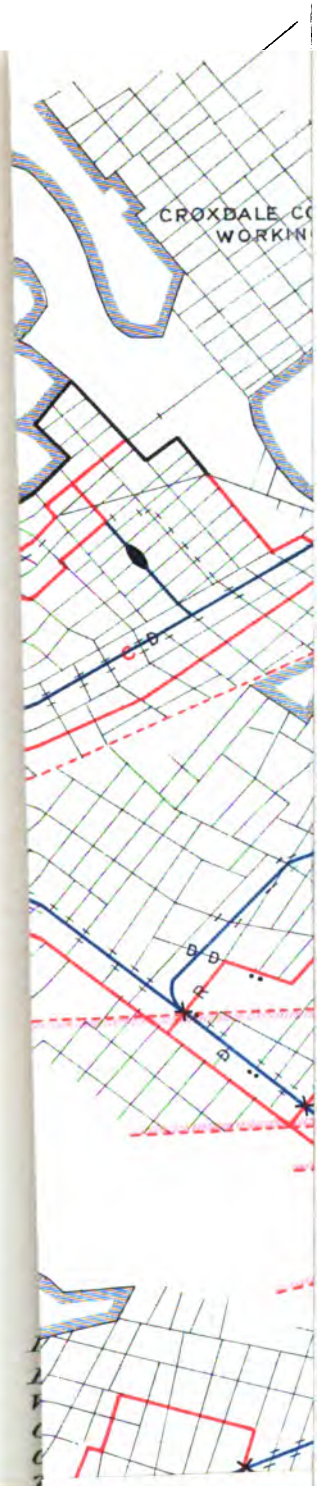
The survivors stated that they had been under no alarm up to the moment of the explosion. The master shifter, or official in charge of the pit, was one of them. He had been in the field of the explosion, but, being in a cabin, was somewhat protected. He was burnt and rendered insensible. At the time of the explosion he was within 100 yards of the downcast shafts. An engineman, in an engine house within 20 yards of the shafts, was also rendered insensible.

The victims in the field of the explosion were all found at or near where their work required them. There was nothing to suggest that up to the moment of the explosion anything had alarmed them.

The victims engaged at or near the working faces, or at points beyond the limits of the explosion, had all moved some distance, bringing their lamps with them in most cases; they had succumbed to after-damp.

The observed indications of the direction of the explosion were not sufficient to point, at all conclusively, to any particular place as being the point of origin; they are not, however, inconsistent with a point of origin which the writers strongly incline to think may be deduced from the consideration of certain other facts. On a portion of the Sunderland Bridge haulage road, between (3) and (4) 100 or 120 yards in length, none of the timber, of which there was a considerable quantity, was displaced; although the timber was swept out of the road extending from each extremity of the undisturbed length for long distances. This undisturbed length of road lay in the direct course of the explosion, and was the connecting link between the sections of the pit on each side of it. The only other roads at this point were the return air ways, one on each side of the intake, and no explosion had passed along either of them. There was nothing to explain why an explosion, on arriving at either end of this undisturbed portion of road, should have had its violence so reduced as to pass it over without blowing out the timbering, and should resume its full force at the other end. On the contrary, this length of road had been raised above the coal for the convenience of haulage, so that there were no stoppings to blow out at the sides and relieve the pressure. It appeared more probable that the origin of the explosion lay in this undisturbed length, and that in some manner the force had increased in both directions. At the time of the explosion two stonemen were engaged in blasting down stone about the centre of the undisturbed length of road. They were removing stone above a stenton in which stood a door leading to the return air way. They had been passed by the master shifter about half-an-hour before the explosion; they were then drilling a shot-hole at right angles to the haulage road and within a few feet of it. After the explosion the shot was found to have been fired, and the bodies of the stonemen were found about 40 yards from it, nearer the shaft, this being a position they might assume in relation to the shot after igniting the fuse. These facts appear to indicate that the firing of the shot and the explosion had been simultaneous. The road where the shot was fired was dry and dusty, and there was timber near the shot on which dust might rest. On both sides of the shot, and within a few feet of it, was a pack wall of loose stones, in the interstices of which coal dust would collect.

The circumstances present a striking similarity to those observed at Seaham and Usworth, viz., the existence of a portion of undamaged road, in the centre of which a shot had been fired, the road on each side of the undamaged portion having been swept by the blast for long distances.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D

The presumption is that the concussion of the shot had filled the air with coal dust, and flame following had ignited the coal dust, which carried the explosion to all parts of the pit where there was a sufficient amount of dust to support the flame. The place where the shot was fired was swept by an air current of more than 20,000 cubic feet per minute, direct from the downcast shaft, so that it is highly improbable that any gas was present.

In this explosion there were two cases where the blast was arrested at considerable distances from the face on coming to places where the roads were damp or wet. One was in the Shieldfield way, where the effects of the explosion ceased near the engine-landing, where there was a pump and the road was wet. The men in the workings beyond had come out after the explosion, and were found dead at the landing; they had been killed by after-damp. The other case was in No. 6 way of the West Pit. The road from the whin dyke inward was damp, and the effects of the explosion gradually diminished from that point, until, before the landing was reached, they had died away altogether. The shafts were wet and the roads near them damp; the explosion did not extend beyond the shafts. No damage was done in the return air ways.

This explosion, like that at Seaham, was almost entirely confined to intake and haulage roads. The two main districts into which it extended were ventilated by currents of air coming down separate downcast shafts.

WEST STANLEY COLLIERY EXPLOSION.

On the 19th April, 1882, an explosion occurred, about 1 a.m., at West Stanley Colliery, in the County of Durham, causing the death of 13 persons and 18 horses and ponies.

The explosion was confined to workings in the Busty Seam, lying at a depth of 280 yards at the shafts. In addition to the Busty Seam, there were worked, at 78 yards, the Shield Row Seam; at 186 yards, the Low Main Seam; and at 194 yards, the Hutton Seam. The workings in these seams were not affected by the explosion.

The downcast shaft is 12 feet in diameter; coal was raised in it from the Busty and Hutton Seams. This shaft was wet. The upcast shaft, 14 feet to the west of the downcast, is 10 feet in diameter; coal was raised in it from the Low Main and Shield Row Seams.

The Busty Seam lies nearly flat, and is of the following section :—

	Ft.	In.	Ft.	In.
Roof—Post.				
Top coal	0	4		
Stone band	0	7		
Coal	3	1	4	0
Band of sagger clay	2	6 to	3	0
Bottom coal	2	6 „	3	0
Thill, grey metal and post	—		—	

Only the upper 4 feet were worked.

From the downcast shaft, haulage roads extended north and south; the explosion did not extend to the north of the shaft. A short distance south of the shaft a road passed to the west into the principal district of the colliery.

The haulage was all performed by horses and ponies. About 150 tons of coal a day were raised from the Busty Seam.

A Guibal fan, 30 feet in diameter and 10 feet wide, placed at the top of the upcast shaft, exhausted the air from the mine. The quantity of air circulating in the Busty Seam was 27,600 cubic feet per minute. It was distributed as follows :—

North side of shaft		4,050
South side of shaft—		
South headways	4,632	
West district—		
East way	6,459	
West „	4,459	
South Cross-cuts	5,000	
		20,550
Stables and scales near shafts		3,000
		27,600

There were 3,596 yards of intake air way, and 2,619 yards of return air way; the average sectional area of the intakes was 32 square feet and of the returns 36 square feet.

The explosion took place when the pit was occupied by a shift of repairers and stonemen.

Clanny safety lamps were used. Gunpowder was used to a limited extent in working the coal, and for stone work.

The Busty Seam at West Stanley was a fiery seam. The coal was dry and very dusty. There was much dust in the workings, as well as on the roads over which the coal was led to the shaft.

The workmen had, under the 30th General Rule of the Mines Act, last examined the mine in the preceding November, when their report was satisfactory. There had been nothing observed by the officials in their examination of the mine, the day before the explosion, to lead them to suppose an explosion possible.

The explosion extended over all the workings, except those to the north of the shaft.

Entry was soon effected into the mine after the explosion. No fires were caused by the explosion; and, as the extent of the workings was small, the pit was rapidly explored, and the bodies of the victims were all recovered on the day of the explosion.

At the bottom of the downcast shaft (1) the cage was blown out of the guides, and the guides were broken. The explosion had not crossed the shaft; some small disturbance on the north side being due to the explosion on the other side. Thus, near the shaft on the north side, some tubs were moved, but not broken; a cabin door had one of its planks forced in to the cabin; an air crossing 90 yards from the shaft, formed of wood, was slightly raised. No timber was blown out here.

At (2), a wood air crossing was blown up. Iron slivers from this crossing were blown 10 yards out-bye. At (3), two quadrants and weights, from switches at a siding, were both blown 15 yards out-bye. At (4), timber in "hole and driving end" was blown out-bye. At (5), portions of doors appeared to have been blown in opposite directions. At (6), an unused man door, said to have been lying on the out-byeside of an air crossing before the explosion, was found lying on the in-byeside of it. At (7), bricks from a door setting, door stanchions, and door bands were blown eastward, or towards the face. At (8), a door was blown westward. At (9), tubs had been traversed by force passing inward. At (10), a kibble, or light tub, with its tram, was blown in-bye. Stoppings and doors were blown as shown by arrow heads on Plan 2. There were some heavy falls on the haulage roads, caused by timber being blown out.

The evidences of flame were abundant. All the men who were killed were either burnt or slightly singed. Near the working faces, in the return air ways, and in the unused passages, much coked coal dust was observed. On the main haulage roads, where the force had been greatest, no coked dust was observed. Near the face of the South Crosscuts a tin water bottle stood upright, and was found to be about half full of water, and it was observed that the solder above the water had been melted by the heat.

There were on the plane of the explosion 18 persons, five of whom survived. The survivors were four men and a boy from the north side of the shaft. There were no fires on the plane of the explosion, and no naked lights, except, possibly, at the bottom of the downcast shaft. Each of the workmen had a safety lamp. Shots were to be fired in the face of both the South Cross-cuts to blast down a depression in the roof stone called a "roll."

The workmen on the plane of the explosion may all be included in two of the divisions already used—1st, the survivors; 2nd, victims in the field of the explosion. The survivors, workmen on the north side of the shaft, had been under no alarm up to the moment of the explosion.

Of the victims five were at the bottom of the downcast shaft, which, in the ordinary course of their work, they were about to ascend. Two were in the South way, and were found near their place of work. The remainder of the victims comprised two shifters, or repairers, at the East flat, who were found within a short distance of their place of work, and four stonemen, working at the face of the South Cross-cuts, also found a short distance from their working places. The position in which these men and their lamps were found will be more fully described.

As the indications (2), (3), and (4) clearly showed that the explosion had come out from the district to the west, the possible places where the explosion might have originated are limited to two—one being in the East way, where the two shifters were working at the face of the wagon-way board; and the other in the South Cross-cuts, where four stonemen were engaged in blasting down stone at the face.

All these men were using Clanny safety lamps, which, after the explosion, were tested in a stationary mixture of lighting gas and air, and did not pass the flame.

The two shifters were found about 30 yards from the face of the board in which they were working. They were lying one over the other, beside a tub, against which they appeared to have fallen, while running out. One of their lamps was found about 6 yards from the face. The other lamp was about 4 feet from the face, under a stone which had fallen from the roof, the lamp being uninjured except that the poles were slightly bent. There was also a prop under the stone; which had probably been supporting it before it fell. The stone had fallen away at a trouble or dislocation of the strata, which crossed the board close to the face. It appeared to have fallen after the explosion, for although the lamp found under, it was buried in dust; the upper side of the stone was clean, and not dusted, as it would have been had it fallen prior to, or at the time of the explosion. The brattice was disarranged, and there was gas near the face. The board appeared to be uneasy and was heaving: it was approaching disturbed ground, intersected with troubles. The movement of the strata in the board continued for several days after the explosion, and the fall in the face extended up the leader of the trouble as far as could be seen. There was always gas in this cavity, and gas could be heard issuing from the floor near the face.

The bodies of the stonemen working in the South Cross-cuts were found at the places shown on Plan 3. The men had been engaged in blasting down a "roll" of stone, which had appeared in the face of both Cross-cuts. Westgarth and Riley working at the face of the fore Cross-cut, and Hutchinson and Douglas at the face of the back Cross-cut.

Westgarth was found about 60 yards from the face of the fore Cross-cut, lying on his face, clean, and so slightly burnt that the burning was not observed in the pit. He had evidently been overcome by the after-damp, while running out. Riley was about 30 yards from the face, clean and unburnt, except that his hair was slightly singed. He also had been overcome by after-damp. The lamps of these men were found clean and uninjured, standing upright on the floor at the face of the fore Cross-cut. Riley's lamp was locked. Westgarth's lamp was unlocked, but not open. A shot here was stemmed and ready to fire, a straw full of gunpowder projecting from it.

Douglas was found in the fore Cross-cut, black and burnt, between Riley and Westgarth. Hutchinson was found in the stenton, or passage between the Cross-cuts, black and burnt. Douglas's lamp was just within the stenton off the fore Cross-cut, about 15 yards from its owner. It was unlocked but not open, and was saturated with oil and covered with coal dust slightly coked. Hutchinson's lamp was in his hand; it was covered with oil and coal dust, and some coked coal dust was on it. It was unlocked, but screwed together.

In the face of the back Cross-cut was lying the result of a shot or shots—stone shot down and not removed. On these stones there was a cracket or wooden stool. A pick was observed within a few yards of the face.

The canvas brattice in the fore Cross-cut was standing, and was charred to a cinder opposite the stenton, as if by a volume of flame coming out of the stenton. The brattice in both Cross-cuts was disarranged, and there was gas next the face, when first reached after the explosion.

Westgarth and Hutchinson were authorised to unlock their lamps for the firing of shots.

A consideration of these observations leads the writers to the conclusion that, at the time of the explosion, Westgarth and Riley had been in the face of the fore Cross-cut (where their lamps were found) preparing to fire a shot. Being in a *cul de sac* they would be preserved from the passage of the blast over them, and the appearance of their bodies and lamps, clean and almost unburnt, confirms this view. Douglas and Hutchinson would appear to have been in the stenton or passage between the Cross-cuts, where Douglas's lamp was found, and also Hutchinson himself with his lamp in his hand. The bodies and lamps of both these men had evidently been traversed by the blast, which would be the case if they were in the stenton. The positions assigned to Douglas and Hutchinson were such as they would naturally have taken while awaiting the explosion of a shot.

The finding of the cracket or stool on the stones blown down would appear to negative the idea that a shot was the cause of the explosion, but from a consideration of all the circumstances the writers conclude that it was. Many cases were observed in some of the other explosions where bodies, much heavier than this cracket, were blown in the direction opposite to that of the explosion; and it is possible that the stone on which it was lying was brought down by a previous shot.

It was difficult to reconcile the way in which the door at the East flat (7) was blown, as well as all the stoppings along the east side of the North Cross-cut haulage road, with the supposition that the explosion began where the shifters were working. There was no means of ignition there save their lamps; and to conclude that the explosion began there, it is necessary to assume that there had been a sudden outburst of gas, which fired by impinging on the lamps with a velocity greater than they could withstand.

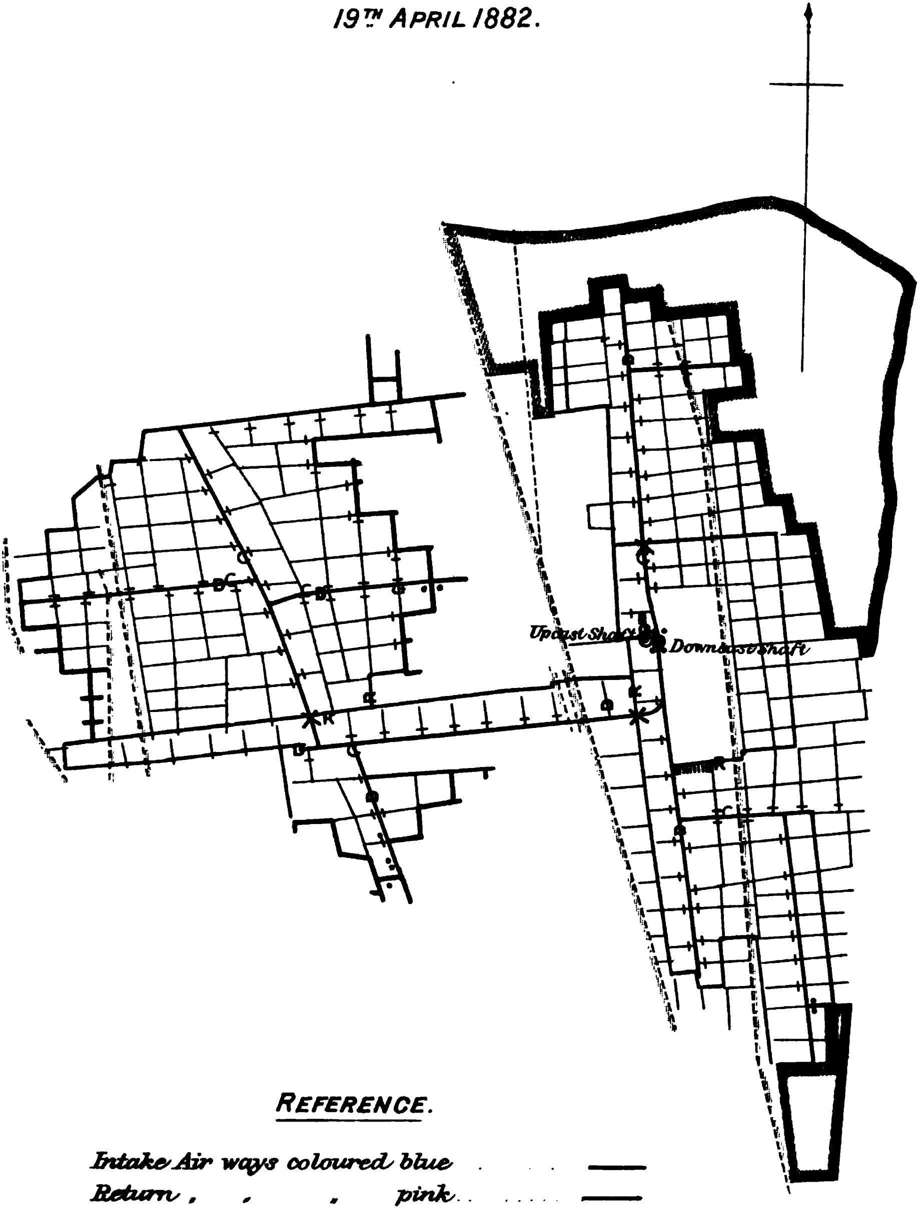
On the other hand, all the indications of the direction of the explosion (except the cracket) agree with the idea that it originated in the South Cross-cuts, and all the conditions necessary for its ignition were present there. The air in the back Cross-cut would contain a small proportion of fire-damp, as the place itself, and the workings through which the air had previously passed, were giving off gas somewhat freely; it is not necessary to suppose that it was present in such quantity as to be detected, and the fact that a lamp would have to be opened to fire a shot renders this very improbable. A mixture of fire-damp and air, where the proportion of fire-damp is too small to be detected on the flame of the lamp, is known to become inflammable when coal dust is also present. There was much coal dust in this place, and possibly some in the stemming of the shot.

In this explosion, all the roadways and open passages in the west and

WEST STANLEY COLLIERY, PLAN No. 1.

Scale 8 Chains per Inch.

19TH APRIL 1882.



REFERENCE.

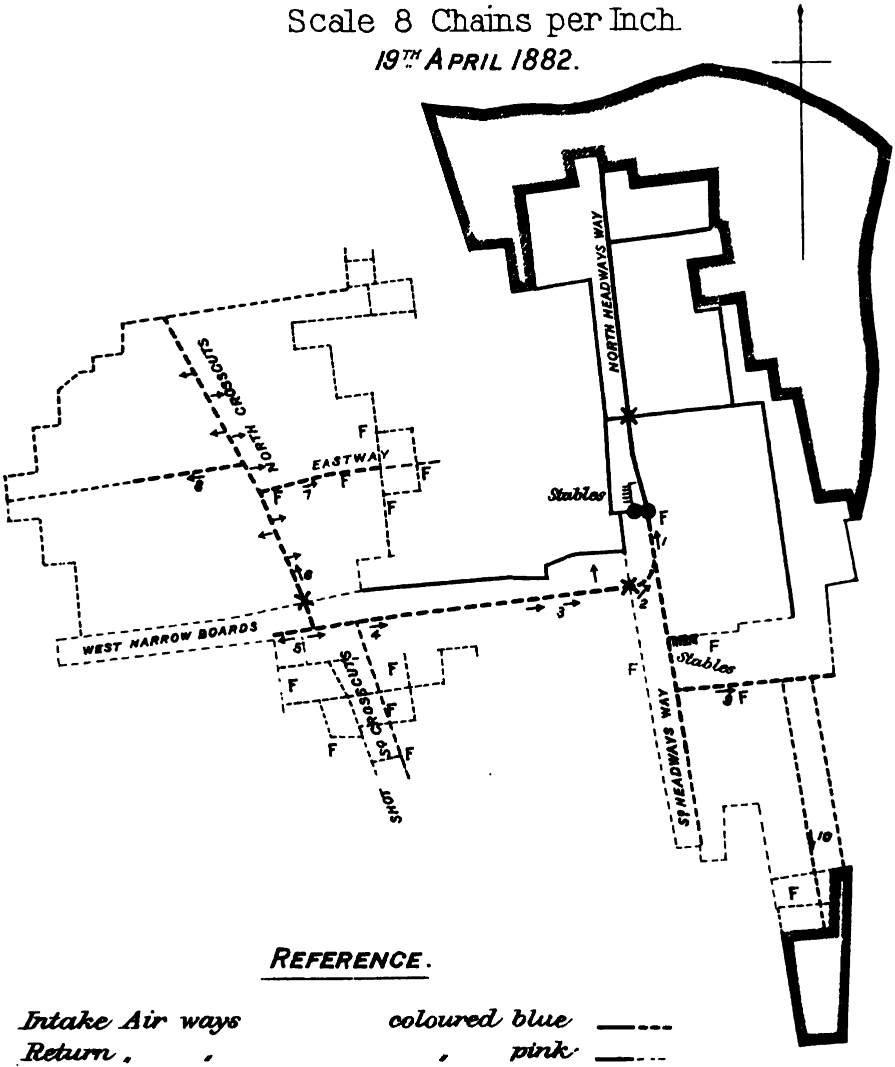
Intake Air ways coloured blue	—
Return " " " pink	—
Working faces thick black lines	—
Old Workings thin " "	—
Goaf shaded	▬
Troubles or Dislocations shaded on dip side	⊥⊥⊥
Doors	D
Regulators	R
Air Crossings, all built	✳
Stoppings	┼
Caution boards or lamp stations	C
Places where bodies of men were found	•

Andw Reid. Newcastle.

WEST STANLEY COLLIERY, PLAN No 2.

Scale 8 Chains per Inch.

19th April 1882.



REFERENCE.

Intake Air ways *coloured blue* ——---

Return " " " *pink* —-..

Working faces and Old Workings " *black* -----

Goaf shaded .... ▬

Air Crossings .... ✛

Places where signs of fire were observed ...... F

Arrows shew direction of force ...... →

This is a diagram distinguishing roads over which the Explosion extended from roads over which it had not passed.

Thick broken lines shew the roads traversed by great force and fire.

Thin broken lines shew places where there were evidences of fire but little force.

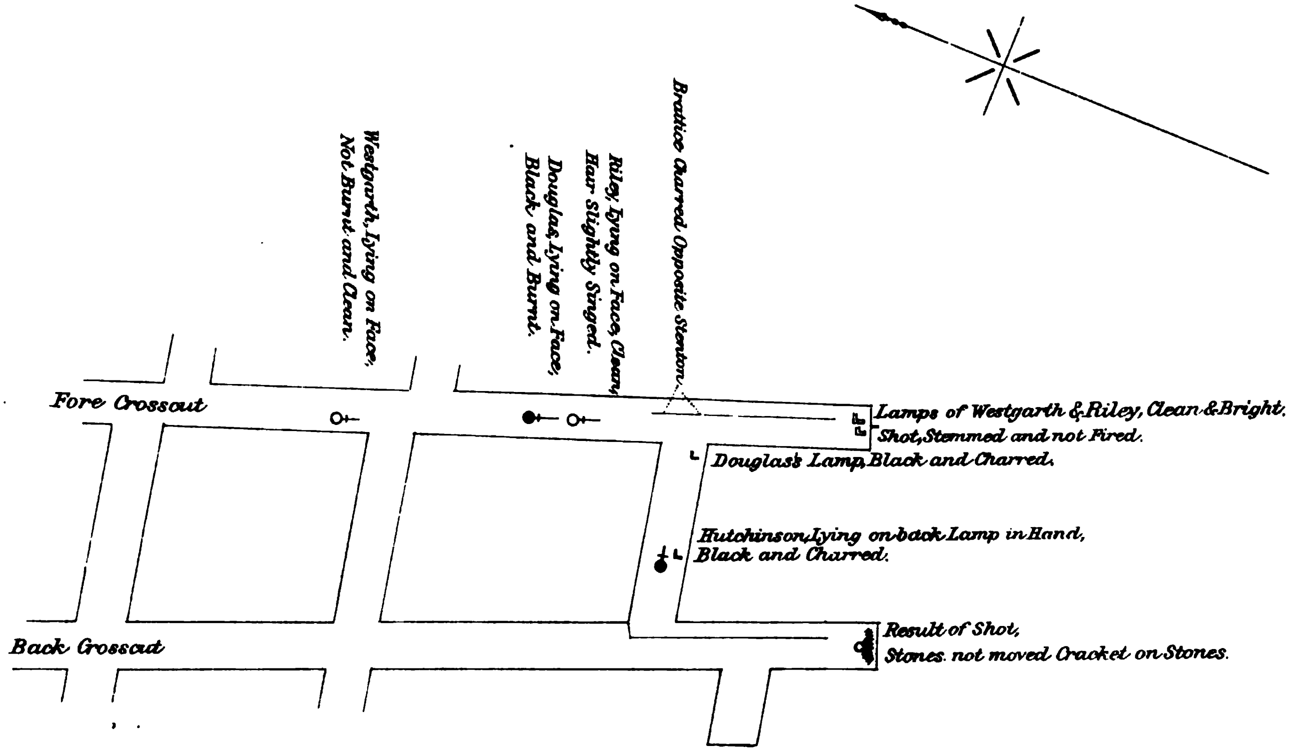
Unbroken line shew roads which had not been traversed by the explosion.

Andw Reid, Newcastle

WEST STANLEY COLLIERY, PLAN Nº 3

ENLARGED PLAN OF SOUTH CROSSCUTS

Scale 1 Chain per Inch.


Westgarth, Lying on Face,
Not Burnt and Clean.
Riley, Lying on Face, Clean,
Hair Slightly Singed.
Douglas, Lying on Face,
Black and Burnt.
Brattice Charred Opposite Stenton.
Fore Crosscut
Lamps of Westgarth & Riley, Clean & Bright.
Shot, Stemmed and not Fired.
Douglas's Lamp, Black and Charred.
Hutchinson, Lying on back Lamp in Hand,
Black and Charred.
Result of Shot,
Stones not moved Cracked on Stones.
Back Crosscut

Andrew Reid, Newcastle

south districts appeared to have been filled with flame, with the exception of the return air road from the west district. In all these roads and passages there was much coal dust, but in the return air way from the west district there was a collection of water where it joined the workings. Connecting the west and south districts, there were, for a distance of about 250 yards, only two roads, an intake and a return. They were both nearly straight and of about equal area. In extending from the west to the south district, the explosion had been confined to the intake air road. The water appeared to have arrested it in the return.

The explosion was arrested at the downcast shaft. The shaft was wet, and consequently the roads for some distance, on each side of it, were damp and free from dust.

WHITEHAVEN COLLIERY EXPLOSION.

At 11·15 p.m., on the 25th April, 1882, an explosion of fire-damp and air occurred in the Whitehaven Colliery, in the County of Cumberland.

The explosion was entirely confined to a limited extent of workings in the main band or seam lying under the sea, and nearly 3 miles in a north-westerly direction from the shafts, which are situated near the town of Whitehaven, and close to the sea shore.

The Plan shows the workings affected by the explosion on a scale of 64 yards to an inch, and a plan on the same scale as the other plans, or 8 chains to an inch, is added for the sake of comparison. A section along the centre line of the stone drift, on a scale of 40 yards to an inch, is given.

The area affected by this explosion was so limited that it is unnecessary to show the whole of the workings, which were extensive.

It will be seen that a dip or downthrow trouble, of 32 yards throw, had been met with; the place A had been driven across the leader or fissure of the trouble into the beds on the other side, and a borehole from the floor of this place proved the seam lying below. A stone drift had been driven, dipping 1 in 6, and cutting the seam at B. The length of this drift, which is shown by dotted lines, was 208 yards, and it was 8 feet 6 inches high by 7 feet wide. It was arched with brickwork for a distance of 56 yards from the leader of the trouble in the direction of the shaft.

When the coal was first reached by the stone drift, gas burst out in such quantity that operations had to be suspended for some months. On resuming, the place C was driven in the coal at right angles to the direction of the drift, and a further passage, D, was driven back to the trouble in the coal; a staple, or slope drift, E, was sunk 32 yards on the leader, forming a double connection with the coal below the trouble and with the workings above.

While the winning of the coal below the trouble was being effected, a current of air was maintained next the face by means of bratticing, shown by a red line; in the stone drift, up to the point F, a brick brattice, 4½ inches thick, strengthened at intervals of about 5 feet by 9 inches of brickwork, was built the full height of the drift, and about 3 feet from one side; beyond the point F, wood brattice plastered with lime was used. The height of the places driven in the coal was 4 feet 6 inches, and their width 10 feet.

The air which returned up the drift on the lesser side of the brattice ascended a short staple about 6 feet deep at H into the level of the coal above the trouble. The direction in which the air passed in the workings above the trouble is shown by feathered arrows.

While the work in connection with securing two roads down the trouble was being carried out gas issued in large quantity from the coal and from the floor. As an extra precaution, only Stephenson safety lamps were allowed beyond the foot of the stone drift; the Davy safety lamp being in general use in the colliery. The Stephenson safety lamp is extinguished by explosive mixtures of fire-damp and air.

About two months before the explosion a fall of stone took place in the return staple up the leader at E; and this place eventually closed entirely, and ventilation by means of the brattice had again to be resorted to. Attempts were made to reach this staple in order to re-open it, but these efforts were frustrated by the quantity of fire-damp, which was more than the current of air available could sweep away.

After the closing of the staple up the leader the air was conducted by bratticing to the face of the place G, then back to the trouble, it then passed along the other side of the brattice to the little staple at H.

Before the explosion, gas was frequently seen on the lamp at the face of the place G. It was known to be present in the place D, and four days before the explosion it was seen on the lamp on the intake side of the brattice, 15 yards from the place C, in the direction of the staple up the leader. The return side of the brattice could not be travelled owing to the presence of gas. Three or four days before the explosion, the state of the air at the top of the little staple at H was examined and found to be nearly explosive.

A current of about 10,800 cubic feet per minute passed down the drift at the time of the explosion.

There was no coal dust on the roads where this explosion took place; all the surroundings were damp—the coal being worked was wet.

This is the most considerable explosion of fire-damp and air that the writers are acquainted with. They have personally investigated, during the last twelve years, almost all the explosions occurring in the North of England, and they cannot point to a case where there was direct evidence of so large a quantity of fire-damp and air exploding.

Pairs of wooden doors at (1), (2), and (3) were blown out in the direction shown by arrows. The framework of brick and stone in which these doors were set was not moved. It was thicker masonry than is common—about 1 foot 6 inches thick. Stoppings 2 feet thick at (4), (5), and (6) were blown down in the direction of arrow. The brick brattice, in the stone drift, was blown over in patches from the return side to the intake side, as shown by arrows An iron pipe in the drift was broken, but this was probably caused by bricks falling on it. Most of the wood brattice was blown down. Two or three props near the top of the staple H, at the end of the brattice in the drift, were blown down. No other timbering was displaced. There was an ordinary amount of it required. Some tubs at the top of the stone drift were moved, but not broken. A light wood stopping, having an area of 9 feet by 5 feet was forced over 1,700 yards away; and a man in a cabin, some distance further, noticed two doors leading from it shake at the time of the explosion. The explosion did not extend into the return air way beyond the top of the little staple at H.

The only evidence of flame was that of burning on the bodies of the victims, and the evidence of a survivor. The writers did not see the bodies of the men, but it appeared from those who had examined them, that they were not much burnt.

There were in the district of the explosion seven persons, each of whom had a safety lamp; there was no other source of ignition of the gas; no gunpowder was being used.

The survivors were three, a man working at a pump at K; he was knocked down by the force of the explosion, but was not burnt, and saw no flame. His lamp, hanging to a prop near him, was extinguished. He passed out towards the shaft in the dark, leaving his lamp. A driver at the landing near the top of the drift at M escaped. One of the workmen down the drift, engaged at the face of the place G, succeeded in reaching the top of the drift.

The men who lost their lives were three pumpers, who were working at the pump near the bottom of the stone drift at O, and one of the hewers from the place G. The lamp of one of the hewers was found at L^1, and that of the other hewer at L^2; the lamps of the pumpers lay on the floor between their bodies and place of work. The bodies of the victims were found near the top of the drift at the points marked X on the plan.

From the position in which the lamps were found it appeared that all the men in the drift had been under some alarm before the explosion, and this was confirmed by evidence of the survivor from the place G. This man stated that when he and his partner were preparing to commence work at G, he saw "flame lifting at the face of the coal." They immediately seized their lamps and hurried out, but were struck down by the explosion when in the place C. The pumpers would also appear to have been alarmed, and to have been retreating before the explosion took place.

It appeared probable that either the issue of gas had so increased, or the quantity of air entering the drift had so diminished that the air passing over the workmen had become explosive, and this alarmed them, then while endeavouring to escape the gas had been ignited at one of their lamps, and the explosion resulted.

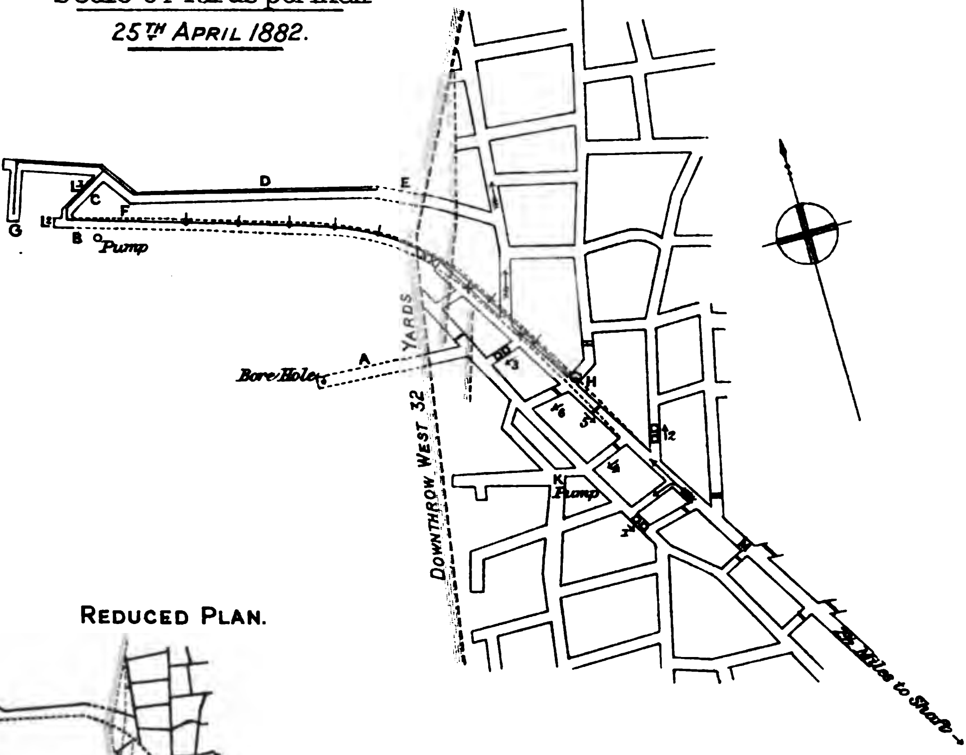
The account of the survivor from the place G rather pointed to the gas being inflamed at the face of the place G before he and his partner left it. When he spoke of "flame lifting at the face of the coal," he said this was not near his lamp, but some distance from it. When workmen observe gas on their lamps they often say the flame "lifted," or elongated; and this is probably what the survivor saw in the place G. In passing out through an explosive mixture ignition had taken place at one of the lamps. The glasses of the Stephenson lamps of the two hewers were broken, but the gauzes were not injured; they were cleaned and fresh glasses put in. On being tested in an explosive mixture one of them passed the flame. The person who cleaned them stated he must, by some mistake, have exchanged the gauzes; and on changing the gauzes it was found both the lamps were perfect. This suggests the possibility of the person who cleaned the lamps not having changed the gauzes, but that, before the explosion, they may have been so changed, and so the defective lamp passed the flame.

If we assume that all the workings in the coal, from the foot of the stone drift, were filled with an explosive mixture, we have 18,500 cubic feet of such mixture, and if we add the space behind the brattice in the

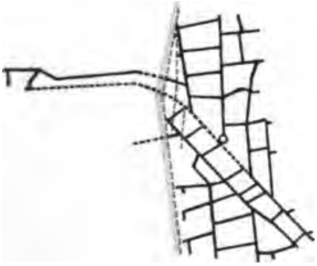
WHITEHAVEN COLLIERY.

Scale 64 Yards per Inch.

25th April 1882.



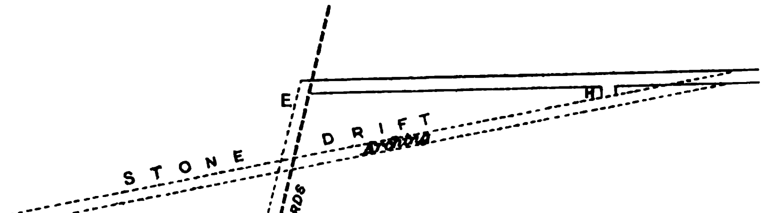
REDUCED PLAN.

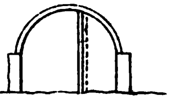


Scale 8 Chains per Inch.

SECTION ALONG CENTRE LINE OF STONE DRIFT.

Scale 40 Yards per Inch.





SECTION OF ARCHING IN DRIFT.

Scale 16 Feet per Inch.

Andw Reid, Newcastle

stone drift we have a further quantity of 14,300 cubic feet, or a total space possibly filled with explosive mixture of 32,800 cubic feet.

There was good reason to suppose that a quantity approaching this did explode. The air was conducted to the face at G, and back to the staple or slope drift at E, and the conditions appeared to be favourable for securing the mixture of such gas and air as there was present. The fact of the brattice in the stone drift being blown over on to the intake side pointed to flame having extended along the return side of the brattice for its whole length.

USWORTH COLLIERY EXPLOSION.

On the 2nd March, 1885, an explosion occurred at Usworth Colliery, in the County of Durham, causing the death of 42 men and boys and 62 horses and ponies. Two of the 42 lives lost were those of officials, who descended after the explosion and perished from after-damp in the return air road.

The explosion was entirely confined to one plane lying at the shafts at a depth of 320 yards, the Low Main Seam being cut by the shafts at that depth. No workings were being prosecuted in the Low Main Seam on the plane of the explosion, but haulage and air roads, driven in or near it, were used in connection with extensive workings in the Maudlin Seam, passing from the former into the latter seam through troubles 200 yards to the east of the shafts, where the two seams were thrown nearly level.

At the depth of 340 yards at the shafts, workings were extensively carried on in the Low Main, Hutton, and Maudlin Seams, but no lives were lost on this plane.

There were three shafts, two downcasts and one upcast. One downcast shaft, 10 feet 9 inches in diameter, was sunk to the lower level at 340 yards. It was divided into two parts by a 3-inch wood brattice, on one side of which coal was raised from the lower level, and on the other side from the plane of the explosion. This shaft was wet. The other downcast shaft was sunk only to the level of the explosion, and was a few yards to the south of the coal-drawing shaft; it was 6 feet in diameter, and was wet. This shaft was not used for raising coal. Pipes connecting an air-compressing engine on the surface with two hauling engines on the plane of the explosion, were placed in this shaft. The upcast shaft for the whole colliery was sunk to the level of the explosion only; it was

100 yards to the west of the coal-drawing shaft, and was 12 feet in diameter. It was used solely as an upcast. In the vicinity of the shafts were three staples from the plane of the explosion to the lower level; one was a downcast, and was provided with ladders forming a travelling way for men; the other two were upcast or return air staples, and one of them was provided with ladders.

The ventilation of the colliery was effected by a Guibal fan, placed at the top of the upcast shaft; it was 45 feet in diameter and 12 feet wide, and was running at its ordinary speed at the time of the explosion.

The general inclination of the Maudlin Seam was eastward, and at some points the dip was considerable, and this dip of the seam was added to by the dislocations passed through being down-throws to the east. The face of the workings to the extreme east was about 160 yards below the plane of the explosion at the shafts; and as the surface at these two points was nearly on the same level, the face of these workings lay at a depth of about 480 yards. The average inclination in-bye on the main haulage road was about 1·9 inches per yard.

From the downcast shaft only one haulage road extended into the district of the explosion. This road, up to the point where it passed into the Maudlin Seam on the east side of the trouble, was above the level of the workings in the Low Main Seam, part of which are shown on Plan 1. From the main haulage road, at 800 yards from the shaft, were branch ways to the south and west. That to the south, known as Barmston way, was abandoned; that to the west was called Lawson's way. At 1,740, 2,030, and 2,350 yards from the shaft were branch roads to the north, known respectively as the Middle North, Low North, and Hitch North ways, and at 2,370 yards from the shaft was a branch road to the south-east known as the Cross-cut way.

The haulage was effected by a steam engine near the shafts, and by two compressed air engines, one on the main road near the Middle North, and the other on the main road near the Hitch North. A tail rope was required in connection with the steam engine as far as the Lawson's way landing; beyond this point the empty tubs ran by gravity to the different landings, taking the main rope with them.

The sectional area of the intake and return air roads was of average size, the intakes being about 40 square feet area, and the returns from 30 to 40 square feet.

The quantity of air passing into the Maudlin Seam on the plane of the explosion was about 33,700 cubic feet per minute. It was distributed approximately as follows. Actual measurement was only made at one point on the main road, a short distance in-bye of the boilers to the east of the shafts:—

Boilers near shaft	Scale	1,000
Lawson's way	do.	1,000
Barmston Old way	do.	1,000
Middle North haulage road	do.	2,000
Low do. do.	do.	2,000
Hitch do. do.	do.	1,000
Do. do. air way		10,000
Narrow boards		13.700
Cross-cut	Scale	2,000

It will be seen that the current was divided into two main splits at the junction of the Hitch North air way with the Narrow Board haulage road. One current, assisted by scales on the various branch haulage roads, ventilated all the pillar workings to the north of the main haulage road; the other, assisted by similar scales, ventilated the whole workings. Part of these two currents, after meeting in the return air road near the air crossing, out-bye from the Middle North, passed over the next air crossing, and meeting the scale from Barmston abandoned way, and that on Lawson's way haulage road, ventilated the Lawson's district. This air current passed under the main intake at a natural crossing near the troubles, and rejoined the main return air, the whole ascending a staple at the troubles to the east of the shafts, and passing to the upcast shaft, crossed the main intake again by a natural crossing near the shafts on its way there.

Gunpowder was not used in working the coal, and only occasionally in stone work.

The Maudlin Seam at Usworth was a moderately fiery seam. Gas was seen in the whole or first workings, and occasionally at the goaf edges; it was not seen on the intake air roads.

The coal was dry and dusty, and the roadways were, with exceptions to be noted, dry and dusty.

The barometer, at the time of the explosion, was standing at 29·90 inches.

The workmen of the colliery had, under General Rule 30 of the Coal Mines Act, last examined the workings of the district of the explosion in July of the year preceding the explosion, and their report was satisfactory, no gas being mentioned as observed.

The officials of the colliery, during their examination of the mine on the day of the explosion, had discovered no unusual source of danger.

The working faces of the district of the explosion were occupied by three shifts of hewers :—

The fore-shift commenced to descend at 4 a.m., and ascended at 11 a.m.
„ back-shift „ „ 10 a.m., „ 5 p.m.
„ night-shift „ „ 9 p.m., „ 4 a.m.

From 5 p.m. to 1 a.m. the pit was occupied by a shift of repairers, stonemen, and a few hewers; the explosion took place when these men only were in the pit: the night-shift hewers were on the surface and on the point of descending. Had the explosion occurred after these men had descended, the loss of life would have been much greater than it was.

About 600 tons of coal per day was raised from the plane of the explosion.

The Maudlin Seam in the district of the explosion has the following section :—

SHALE ROOF.

	Ft.	In.
Coal	2	6
Splint	0	3½
Coal	1	8
Band	0	1
Bottom Coal	0	7

Inferior fire-clay floor.

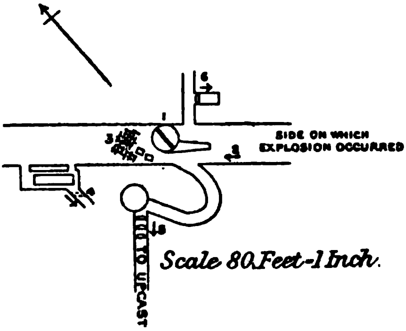
The part down to the 1 foot 8-inch coal only is worked, the band and bottom coal was taken up to make height on all the horse roads.

Clanny, Davy, and Stephenson safety lamps were used.

Damage done to the coal-drawing shaft near the plane of the explosion prevented access to the mine for some time by this shaft, but explorers descended within an hour or two by means of a kibble in the smaller downcast. A large fall near the shafts barred further progress for more than a day; an attempt to reach the workings beyond the fall by the return air way, which was quite open, resulted in the loss of two lives by after-damp. A passage over the fall having been opened, exploration was carried on until the Middle North way was reached, when the passage over the fall near the shafts appeared likely to close, owing to further movement of the stone, and operations were suspended in-bye of this place until it was made secure. This was done on the 7th March, and a party of explorers passed in-bye to the point which had been previously reached, and found the intake full of smoke. This, indicating a fire somewhere ahead, caused the withdrawal of the explorers and the erection of a stopping in the intake, at a point marked A on Plan 1, where only two roads existed, as shown on the plan. A stopping was shortly afterwards erected in the return air road as well. About the 13th March the stopping in the intake was removed, and by bratticing this road the explorers proceeded to the Middle North way and recovered the bodies there. Operations were then resumed on the main road; but a rapid rise of temperature, as the explorers went on, led to a second withdrawal of the workmen, and the building, in the intake, of a stopping, at the point B, on Plan 1. Exploration was then continued by means of a travelling way between the Middle and Low North haulage roads, until the latter road was reached, and the main intake near it examined and found cool and free from any appearance of fire; a stopping was then built at the point C, Plan 1, and side stoppings erected in all the places leading from the main intake, between B and C, isolated the fire. Exploration was then carried on without any further interruption except that arising from the large falls of roof, and the last body was brought to the surface on the 16th April.

The following indications of the force and direction of the explosion were observed. The numbers on Plan 2, and on the illustrations in the text, refer to the same observations. Want of space has prevented the marking of some of the observations, shown on the sketches, on Plan 2 :—

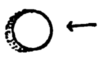
(1) The wood brattice and cage guides, in the downcast and coal drawing shaft, were broken and disarranged for 10 yards above the plane of explosion. Some damage was done in this shaft for about the same distance below the plane of explosion. At the moment of the explosion some men in the cage at the surface, who were about to descend the shaft, observed a heavy gust of air laden with dust ascend the pit. Lights near the pit top were extinguished. A man working in the Hutton Seam level, 20 yards below the plane of explosion, and within 9 yards of the shaft, was blown over but not seriously injured. No damage was observed in the Hutton Seam level.



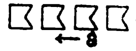
At (2) tubs laden with coal were blown past the drawing shaft about 10 yards. At (3) timber was blown out or knocked out by tubs striking it and thus caused a fall of stone. At (4) a stopping above the flue from a multitubular boiler was blown out towards the return. The coal next this flue was found to be on fire after the explosion. The fire had been burning for some time before the explosion, and did not appear to have been caused by the explosion or have any connection with it. The boiler was not injured. The gauge glass was not broken. A paraffin lamp hanging against the wall at the fire hole end was not disturbed and a glass globe on it was not broken. About 150 yards from the downcast and drawing shaft, and in an abandoned way, were two regulating doors, shown on Plan 1. The door nearest the shaft was blown down but not broken; the second door, within a few yards of the other, was not moved.

The force of the explosion appears to have died out within a few yards of the shaft. Between the shaft and the door blown down, was a pile of loose timber undisturbed, and timber set in the road was not moved.

The props between the shaft and the door blown down were coated with dust on the in-byeside, or side opposite to the direction of the blast, thus—



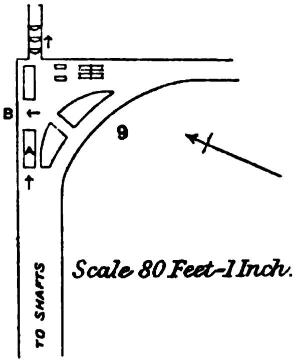
An arched road, as shown on sketch, connected the two pits and was about 40 yards long. Two men were preparing to sink the smaller downcast shaft to a lower level; they were near the bottom of it at the time of the explosion and were the only survivors on the plane of the explosion. They were knocked about by the force of the blast, but were not seriously injured, and had no bones broken. One of these men had an eye injured by rubbish or dust being blown against it, and he was marked about his face by coal dust. They had placed in the shaft, or at one side of it, a few planks to keep the shaft water off them while at work; these planks were blown down, but no damage was done to the shaft. At (5) the doors in a road leading from the smaller downcast pit to the upcast pit were blown out, and in the direction of the upcast: a large quantity of coal dust was blown into the return, but no disturbance was observed through these doors. The timber supporting the roof was not moved. The props were coated with dust on the side opposite to the direction of the blast. The upcast pit was not affected by the explosion. A gust of air had ascended it and blown open two doors on the surface leading into the Fan drift; one had closed again, the other was found open. At (6) the brickwork and door of a loose box, in which a pony stood, was blown inwards. The pony was not injured, and was the only surviving pony on the plane of the explosion. At (7) a large balk of timber, about 12 inches square and 12 feet long, was supporting the roof, and rested, before the explosion, on masonry at one end and on a prop at the other. The prop was blown out and the balk was blown on the fulcrum of its supported end against the next balk, and in the direction of the shaft, indenting the balk where it had struck it. At (8) a number of empty tubs standing in the empty way near the shaft had their ends furthest from the shaft bent towards the shaft.



Scale 24 Feet-1 Inch.

(9) A haulage engine and two multitubular boilers stood here. The smoke box door of the boiler nearest the shaft at A was forced against the tubes. The safety valve was nearly torn off. The steam pipe, at its junction with the steam dome, was broken, and the gauge glass was broken.

The brickwork, forming the side of the boiler house at B, was forced, as shown by arrow. The gauge glass of the other boiler was broken. The smoke from these boilers passed along a flue under three man-doors. These doors were blown into the return, and the damper of the boiler flue was blown about 30 yards to the return. Timber set in the return, a few yards from the doors, was not disturbed. It was coated with dust on the side opposite to the direction of the blast.

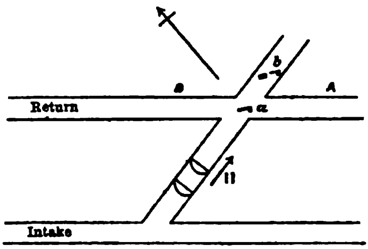


Scale 80 Feet-1 Inch.

After passing the haulage engine, going in-bye, the main haulage road was much blocked by fallen stone, the falls extending as far as the troubles shown on Plan 1. These falls, as well as others, were caused by the force of the explosion blowing out the timber supporting the roof stone, which fell in consequence. Near the troubles the road was completely closed, and no passage was available until two days after the explosion. A balk at (10) let into the sides of the road, and not blown down, showed that force had been exerted on it towards the shaft.

Passing in-bye from the troubles the road was, for a considerable distance, little obstructed by falls of stone; top coal had been left next the roof stone There was little timbering in.

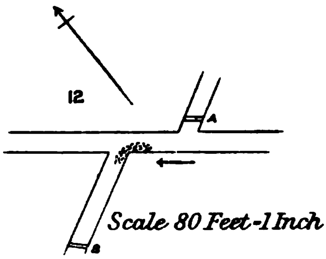
At (11) were two man-doors in a passage leading from the intake to the return. These doors were, with bricks and a quantity of coal dust, blown to the return. At (*a*) was a door crook, and at (*b*) a door crook and bricks. In the direction A, the dust was deposited on the sides of things opposite to the direction of the blast; in the direction B, the dust was on the sides of things in the direction of the blast.



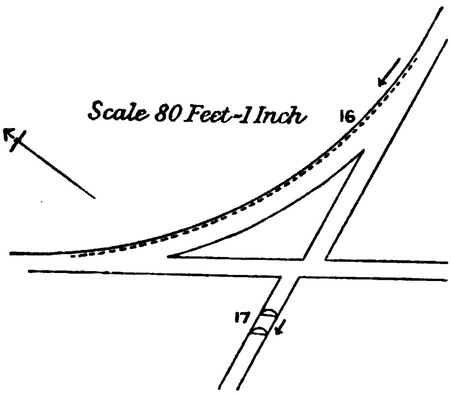
Scale 80 Feet-1 Inch.

With one exception, to be noted hereafter, in all observed cases, force had been exerted on the stoppings from the intake and haulage roads to the return or working face. Many of the stoppings were stowed with stones on the return side and were not blown out but were pushed over next the top; others, of a lighter nature and not stowed behind, were blown out and to the return.

Near (12) a phenomenon was observed that appeared to indicate force coming on to the intake from the side, and also force having a direction in-bye; the stoppings on the left side going in-bye were set close to the intake as at A; on the right side they were set back some yards, as at B, and the space between them and the intake used as a deposit hole for dust and rubbish. This dust and rubbish was, in some cases, strewn in-bye, as shown. There could be no doubt that the force of the explosion travelled out-bye past these points, as shown by arrow. Air would be forced into these places against the stoppings, and the recoil would appear to have brought out some dust and rubbish, and from the direction in which it was strewn, the air would appear to have reversed.



(13) A set of empty coal tubs was standing here and they afforded unmistakable evidence of having been traversed by a force passing outbye. These tubs were connected by a main-and-tail rope with the haulage engine near the shaft; the tail rope prevented the tubs being forced to the shaft, and the upper parts of the tubs furthest from the shaft and those first struck by the explosion, were broken off from the trams or lower parts and carried some yards in the direction of the shaft, leaving the lower parts in connection with the tail rope. A compressed air receiver stood near these tubs. The air pipe from its in-bye end was broken right across close to the receiver. The flat ends of the air receiver were dusty, and there was most dust on the outbye end, or end opposite to the direction of the blast. At (14) and (15) props supporting tail rope sheaves were broken and bent to the shaft.

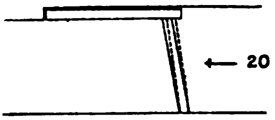


(16) Here was a curve in the main haulage road, on one

side of which had been skating deals, shown by dotted line, against which the tub sides pressed while passing round the curve. These deals were blown out-bye. The horse road into the Lawson's district left the engine plane here. Doors at (17) on this road were blown towards the face, and some timber was displaced, causing a fall of stone. The explosion had not passed far up this road. At (18) were two regulating doors in an abandoned way, known as the Barmston way. These doors were blown down, as shown by arrow.

(19) A brick arch air crossing stood here, and was blown out. It will be observed that the return air crosses the intake at two points nearer the shaft. Both these crossings were natural crossings, and were not affected by the explosion.

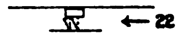
(20) Here a prop under a running balk, or balk set parallel to the side of road, showed out-bye force.



Scale 8 Feet-1 Inch.

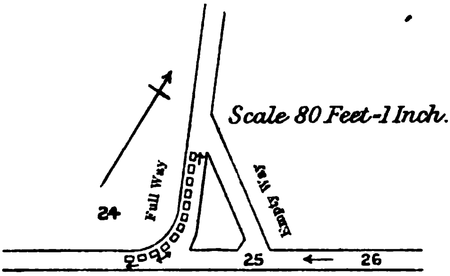
(21) A brick arch air crossing stood here, and was blown out, and coal dust was blown towards the return.

(22) Short props, or punch props, set under one end of balks, and resting on ledges in the stone, were forced out-bye.

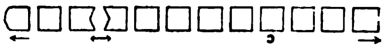


(23) A brick arch air crossing here was blown out. The main haulage road was, from (16), passing in-bye, much blocked with fallen stone as far as (32). The rapper handle, near the Middle North way end, was found 29 yards out-bye from the place where it was fixed; but this may have been caused by force applied to the rapper wire at some distance from it.

Scale 8 Feet-1 Inch.



Scale 80 Feet-1 Inch.



Scale 24 Feet-1 Inch.

(24) The Middle North horse road left the main road here.

A set of eleven full tubs and an empty water tub stood here, as shown in sketch, and afforded indications of having been struck by a force passing out-bye and into the Middle North. Commencing nearest the shaft:—The out-bye end of 1st tub was bent out-bye. The 2nd tub was not damaged. The 3rd tub was in such a position that its in-bye end was exposed to a force coming from in-bye on the main road; this end was forced out-bye.

The out-bye end of the 4th tub was slightly bent in-bye, as though a division of force had taken place between it and the 3rd tub. The 5th, 6th, 7th, and 8th tubs were not damaged. The 9th tub was an empty water tub, the iron frame round the top and part of the woodwork were torn off, and were found lying on the 7th tub. The position of this detached portion indicated force passing out-bye from the Middle North, but the way in which it was bent indicated force passing into the Middle North. It had apparently been moved before being observed. The road into the Middle North lay past these tubs, and the detached portion of the water tub, if lying on the road, may have been carried back by workmen and put to one side. The 10th and 11th tubs were not damaged. The 12th tub had the top part of its in-bye end blown in-bye and into the Middle North. Past these tubs, and going into the Middle North, was a heavy fall of stone, which extended into the stables occupying the side of the Middle North haulage road. The explosion did not pass these stables. On the main haulage road, at (25), some sacks of hay were observed. These sacks were, before the explosion, in the empty way of the Middle North, and appeared to have been moved in the reverse direction to that of the explosion.

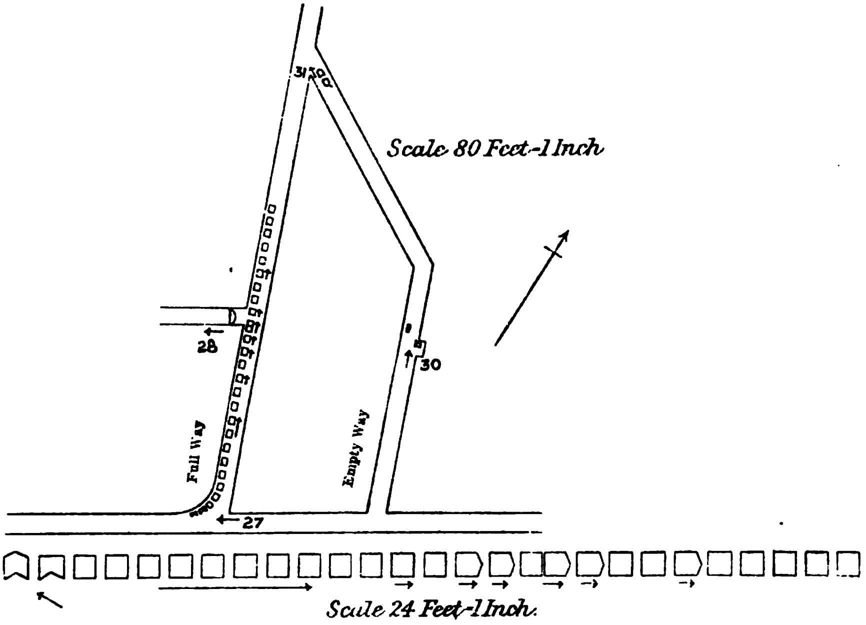
(26) Here a set of 30 full tubs afforded unmistakable evidence of force having passed over them, as shown by arrow, and from in-bye to out-bye. There were some falls of stone on these tubs, but the marks of force were not such as could have been caused by stone falling on them. This set of tubs extended past the Middle North empty way.

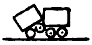
From B to C, Plan 1, on the main haulage road, was not examined, owing to this portion being barred off by stoppings put in after the explosion to isolate a fire.

A road, connecting the Middle North and Low North haulage roads, and parallel to the main road, was made use of to pass the closed part. This road was called the travelling way. There had been no great force exerted on the travelling way. Some chocks were disarranged. A door next the Low North horse road, at (28), was blown as shown by arrow, and bricks from the door frame were scattered along the road. The door crooks were found 20 or 30 yards along the road.

(27) At the Low North way end there was in the full way a set of 27 full tubs, the two first tubs standing nearly in the main road, the remainder extending up the full way. Beginning with the tubs nearest the shaft:—The first two tubs were forced against the side of road and had their sides bent, as shown by arrow. The 3rd, 4th, 5th, 6th, 7th,

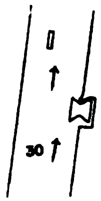
8th, 9th, 10th, 11th, and 12th tubs were not damaged, but the chains connecting them were taut, as though the 1st and 2nd tubs, having been blown off the rails and jammed against the side, had prevented movement further than the chains would allow. Some stone had fallen on the 1st and 2nd tubs, but the damage done to them was not such as would be likely to be caused by stone falling on them. The 13th tub had the top part of the in-bye end blown in-bye, or up the Low North way. The 14th tub was not damaged. The in-bye ends of the 15th and 16th tubs were bent in-bye. The 17th tub was tilted up against the 18th tub thus :—





The in-bye ends of the 18th and 19th tubs were bent in-bye. The 20th and 21st tubs were not damaged. The in-bye end of the 22nd tub was bent in-bye. The remainder of the tubs were not damaged. These tubs extended past the travelling way, the door of which, as already mentioned, was blown, as shown by arrow. At (29) were two doors before the explosion. These doors were blown towards the face of the Low North way, and were buried under a large fall of roof, which almost blocked the road. A short distance beyond this fall was the working face of the Low North way, and no further damage was observed.

Returning to the main haulage road, 22 yards in-bye of the Low North full way, was the empty way. About 20 yards up this road, at (30), was the upper part or box of a tub laid to one side. It had been traversed by force, as shown by arrow. The out-bye end was broken and forced in-bye, and the in-bye end was broken by being forced against a solid projection on the side of road. Part of the side of this tub was found some yards in-bye of the tub.



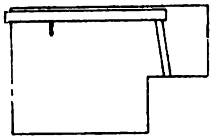
Scale 24 Feet-1 Inch.

(31) Here were two empty tubs; one of them had both ends bent in-bye, or to the face of the Low North, the other tub—and nearest the main haulage road—had been twisted round, and the iron band binding the top torn loose. It afforded no decisive indication.

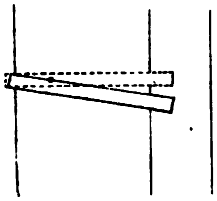
Passing in-bye from the Low North on the main road, the road was much blocked by fallen stone, most of the timber having been blown out, but afforded no indications as to direction of force; things that would have afforded information being buried under the fallen stone. This continued until indications of passage of any force ceased almost entirely. The only indication of direction of force this length of road afforded was dust, which was found deposited on such timber as was left standing on the side nearest the shaft.

There were, however, at (32), two things observed which appeared to indicate force having passed in-bye. It became necessary to examine these with great care. A balk, supported at one end by insertion in a hole cut in the side of the road, and, previous to the explosion, by a prop under the other end, was found unsupported by any prop, and the loose end pointing in-bye.

32

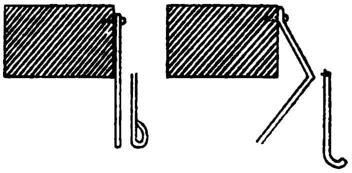


Scale 8 Feet-1 Inch.



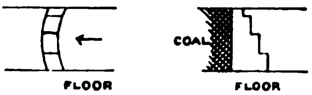
32

Scale 1¼ Foot-1 Inch.



The road was examined, and a prop of the length required to support the balk was found a few yards out-bye. It was observed that the balk had supported the rapper wire (a rope made of iron wires, and about the thickness of a pencil); this wire had been threaded through an iron hanger nailed to the balk, about 2 feet from its supported end and on its out-bye face. The ring at the end of the hanger was found to have been forced open, and the hanger itself was bent, as shown in the sketch. It appeared most probable that some weight had, at the time of the explosion, fallen on the rapper wire in-bye of the balk, and that this had put a strain on the hanger, bending it as shown, and bursting open the ring. A force applied to the wire capable of doing this, would be likely to twist the balk in the direction in which it was found. Some timber, a few yards in-bye of the balk, had fallen from a considerable height at the time of the explosion. The other indication, appearing to point to force passing in-bye, was a column of brickwork (the remains of a door frame), next the side of way. As shown in the sketch, the brickwork was slightly curved in-bye, about 3 inches out of the perpendicular. It appeared more probable that the curving of this masonwork was due to pressure of the roof than to any force exerted on it at the time of the explosion.

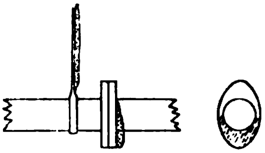
32



Scale 8 Feet-1 Inch.

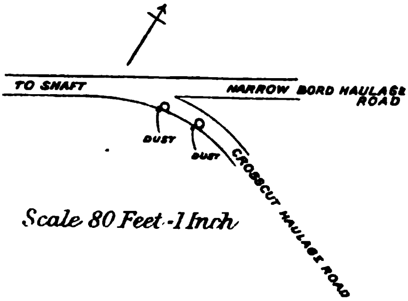
Beyond here (32), on the main haulage road, for a distance of about 150 yards, little damage was done; and when this part of the mine was arrived at it was hastily assumed by some that the limit of the explosion had been reached; but it was found that the damage recommenced, and extended far beyond this undamaged length of road. Starting from the out-bye end of this undisturbed section of road, the first 70 yards was a stone drift, driven to cross a downthrow trouble of 10 yards. There was, near the leader or fissure of the trouble (which was crossed near the outer end of the stone drift), and for a distance of 10 or 15 yards, heavy timbering, which was undisturbed. Large balks were placed at intervals of 2 or 3 feet, to support the roof. Just beyond this timbering was a wood fence to protect the compressed air pipes at a bend; this fence was undisturbed. Up to this bend, the air pipes were, in the undisturbed section of the main road, supported at a height of about 4 feet from the bottom, and at intervals of about 5 feet, by iron bands nailed to the timber, and passing round the pipes. From the bend pipe passing in-bye they rested on the floor. Beyond the bend pipe there was, for a distance of about 60 yards, very little timber in the drift, only light pieces let into the stone near the roof to carry the rapper wire. These were not displaced.

Near where the drift cut the bed of coal on the dip side of the trouble was, on the north side of the road, a stenton or passage in the coal, connecting the intake and return air ways. Up to this stenton, in the undisturbed section, there was a deposit of fine coal dust on the out-bye face of the timbering, and to a smaller extent on the in-bye face. On the hangers and flanges of the air pipes, where they were above the bottom of the road, there was a deposit of dust on the out-bye side, and this deposit was thickest next the lower part of the flange.



In the stenton already mentioned were two man-doors before the explosion; these doors had been blown in the direction of the return (33). Doors set in light brickwork, and offering a surface of 30 or 40 square feet, are easily displaced, and such displacement affords no indication of the passage of great force. The remains of the doors, a large quantity of fine coal dust, some straws, used as a fuse for firing shots, some clothing, a hewer's wooden stool, and an old shovel were blown a few yards in the direction of the return. There were about six straws fastened together, but one was found sticking in a crack in a fragment of wood. The timber supporting the roof in the stenton and return was not disturbed.

Nearly opposite the stenton, on the main road, was an empty coal tub undamaged; a few yards further in, workmen's tools, placed upright against the wall side, were not blown over. Two Clanny lamps were found near the stenton, one was slightly damaged near the top, but the glass was unbroken; the other was broken in two pieces, the poles having been snapped. It was locked, and the bottom part and the poles were in one piece, the glass being broken; the upper part was crushed flat. About 20 yards from the stenton, going in-bye, two undamaged Clanny lamps were found. A little further in-bye, timbering was undisturbed, with the exception of a prop, to which a notice board was nailed; this prop was slightly inclined in-bye at its upper end, where the board was nailed. A rapper and its framework were undamaged. A compressed air engine was undamaged. A workman's bottle was found standing upright, and his Davy lamp was hanging on a prop uninjured. Where the Hitch North haulage road leaves the main road, two full tubs were standing undamaged. They were, as well as props in the road near them, coated with coal dust on their in-bye ends or sides. Skating deals, similar to those already described, were unmoved. The first pair of canvas doors hanging in the Hitch North road (34) were blown down, and towards the face, one door was observed 3 yards from where it had hung, and lying on the rapper wire. The second pair of canvas doors on this road were not blown down. At a landing, about 180 yards along the Hitch North road, were some full and empty tubs; these tubs were not damaged, but appeared to have been forced in-bye a short distance against each other. There were no indications of any great force having traversed the Hitch North way. Returning to the stenton in which the doors stood, it was observed that out-bye, from the stenton in the return and in the direction of the staple shown on Plan 1, the props were coated with dust on the in-byeside, or in the direction of the explosion. This deposit of dust was thickest nearest the stenton. On the main haulage road, going in-bye from the stenton, the balks next the roof had a thin coating of dust on their out-bye sides, and this was so for a short distance down the Cross-cut haulage road. Large sheaves or rollers, having a vertical axis, and placed near the floor for a few yards down the Cross-cut haulage road, from its junction with the main road, were coated with dust on their out-bye side.

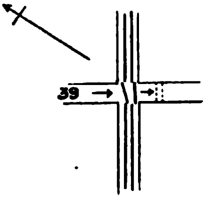


Passing in-bye, from the junction of the Hitch North with the main road, a distance of 20 yards, another junction was arrived at. The main road continued in a straight line, and was called the Narrow Board, whilst a road called the Cross-cut passed to the right. Taking the Narrow Board haulage road, the disturbance was observed to recommence within about 10 yards of the junction. (35) Here an old door, which had been used as a lime board, was found in two parts, the smaller part furthest from the shaft. It was not definitely ascertained where this door had stood before the explosion, but probably it had been placed against the side, near a cabin a few yards out-bye from where it was found. At (36) was some timber displaced, and showing force passing in-bye. A gate on one of two stables, at (37), was wrenched off its hinges, and blown into the stable a few yards. Past the stables the road was blocked with falls of stone, and these falls continued more or less to within a short distance of the face.

At (38) was a set of tubs standing on the Narrow Board haulage road, and connected at the end nearest the shaft by a chain to the side of way. This set consisted of 24 tubs; the first 17 tubs were buried under a large fall of stone, and could not be observed. The 18th and the 19th tubs were not injured. The 20th tub had its in-bye end bent out-bye. The

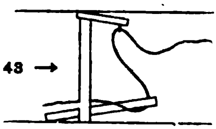
21st tub was lying on its side, but not damaged. The 22nd was not damaged, except where a wheel of the 21st tub had struck it. The 23rd tub had its out-bye end forced in-bye. The upper part of the 24th tub was torn off the tram, and found a considerable distance nearer the face.

At (39) the rails appeared to have been struck by a force, as shown by arrow, or sideways, and were torn from the sleepers.



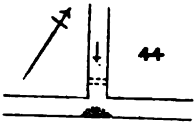
Scale 80 Feet-1 Inch.

(40) Here were two canvas doors before the explosion. These doors were carried in-bye a considerable distance. At (41) a balk, unsupported at one end, had the loose end forced in-bye. (42) Here was a landing or station, from which the tubs were drawn out-bye by engine power. The landing extended from the Narrow Board haulage road up a road to the north. Some tubs were in this landing, and the following was noted:—The 1st tub was broken up, the upper part was wanting. The 2nd and 3rd tubs were water tubs, and were partly filled with water. The out-bye end of the 2nd tub was forced in-bye, and part of the in-bye end of the 3rd tub was blown in-bye; the 4th tub was not damaged. Part of the ironwork of a tub was lying opposite the 2nd tub, and woodwork, which appeared to belong to the 1st tub, was lying opposite the 4th tub. Some other tubs were glanced at, but did not appear much damaged; they were partly buried under falls of stone. (43) Here was some timbering and rapper wire, showing force passing in-bye.



Scale 8 Feet-1 Inch.

At (44) was the only example observed by the writers at Usworth of a stopping having been blown on to a main haulage road.



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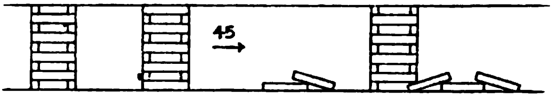
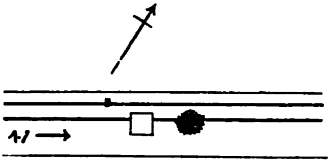


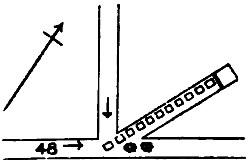
Scale 8 Feet-1 Inch.

At (45) were a series of chocks supporting the roof; one chock was blown down, and the pieces making it up were scattered in-bye, as shown in sketch.

At (46) the props standing were coated with dust on the in-bye face. (47) Here a tub, which had stood before the explosion against a chock, had been forced over the chock and in-bye; it was not standing on the rails, but at right angles to them. It was on its wheels, but had apparently been overturned in-bye, the coal emptied out of it, and replaced on its wheels by the explosion.



Scale 24 Feet-1 Inch.



Scale 80 Feet-1 Inch.

At (48) was a passage in which full tubs were placed in order to be ready for haulage by engine power. Eleven tubs were standing here. The two first tubs had been overturned in the in-bye direction, and part of the coals emptied out of them. Two heaps of coals lay a few feet in-bye of the tubs. The tubs had been replaced by the explosion on their wheels. Past this point the face was neared, and the force appeared to decrease. Timbering was not displaced.

Returning to the junction of the Narrow Board and Cross-cut haulage roads and proceeding into the latter—

For a few yards from the junction disturbance was not observed, skating deals and timbering were not moved. At (49) had been two man-doors in a passage leading into the return. These doors and the brickwork framing were blown in the direction of the return; the bricks, door crooks, and other parts of the doors were found lying about 20 yards in that direction, and amongst timber standing undisturbed. The props in this passage were thickly coated with coal dust on the side opposite to the direction of the blast. At (50) were two canvas doors before the explosion; these doors were blown in-bye. A short distance down the Cross-cut extensive falls of stone had to be passed over, and these falls continued almost to the face. (51) Here sets of full and empty tubs afforded unmistakable evidence of force having traversed them in the direction of the face. The empty tubs were twisted and torn in a most surprising manner. From these tubs, to within about 100 yards of the face, the roof-stone of the Cross-cut haulage road had fallen continuously. Near the face indications of force decreased, and the timber was not displaced. The Right Hand haulage road was much blocked by falls of stone, most of the timber having been blown out. At (52) timber left standing indicated the passage of force in the direction of the face. Balks supported, before the explosion, at both ends by props, had one prop blown out, and the loose end of the balk was forced in-bye. The timber left standing in this road was coated with dust on the side opposite to the direction of the blast. The explosion had not passed to the face of this road.

The return air roads were examined, and it was clear that no explosion had traversed them. They were, in every respect, in their ordinary state, except at points where doors, air crossings, or light stoppings had been blown to them by force passing from the intake.

The evidences of flame were as follows :—One of the surviving workmen at the bottom of the smaller downcast shaft was burnt, but not seriously; his partner was not burnt. These men stated they saw dust burning near the coal-drawing shaft after the explosion. A man at the coal-drawing shaft in the lower level saw sparks. Brattice cloth was found burning, after the descent of explorers, at (8). Men were burnt at (9), (17), (24), and (25), and ponies at the stables near (18). A horsekeeper was burnt in the stables by the side of the Middle North haulage road. On the main haulage road, between the Middle and Low North ways, a fire had burned for some time after the explosion. At (27) two men were burnt. At the face of the Low North way, at F', F', F''', F'''', men were burnt, and coked dust was observed on the timber. In the travelling way, parallel to the main road, and connecting the Low North and Middle North haulage roads, coked dust was observed on the timber and on the coal. At F' and F'', between (32) and (35), on the main road men were burnt.

A short distance along the Hitch North haulage road, at (34), coked dust was observed on timber next the roof, to which a canvas door had been nailed; it was deposited in the direction of the explosion. At (37) ponies were burnt. At (38) a man was burnt. At (39), in a passage (a *cul de sac*) driven about 30 yards from and at right angles to the haulage road, were three props near the face. Coked dust was on these props, and on the sides next the face, or sides opposite to the only possible direction of the explosion. At (43) coked dust was observed on a balk, and on the side opposite to the direction of the explosion. At F' and F'', near the face of the Narrow Board haulage road, coked dust was on the sides of the timber, opposite to the direction of the explosion. At F''', props were coated with coked dust all round.

At (49) coked dust was observed on a sheave support and on timber on the sides opposite the direction of the explosion. At F', F'', F''', at the face of the Cross-cut district, coked dust was on the timber and on the floor, and near here a pick handle was charred.

At the time of the explosion there were on the plane of the explosion 42 persons.

There were the following fires and naked lights on the plane of the explosion :—Open lights at the bottom of the smaller downcast, and at the boilers on each side of the downcast shaft. Boiler fires on each side of the downcast shaft. Coal on fire in a flue near the downcast shafts. Each of the workmen, except those at the boilers and shafts, had a safety lamp.

A shot was to be fired at one point only—for the purpose of removing side stone.

Dividing the workmen on the plane of the explosion as before, the survivors were only two, viz., the workmen at the bottom of the smaller downcast shaft. These men stated they had been under no alarm up to the moment of the explosion.

The victims, in the field of the explosion, who had been traversed by force, or flame, or both, were, a lad firing a boiler on the west side of the coal-drawing shaft. He was not burnt, but had been thrown upon the hot and wet ashes at the fire hole, and was scalded. He died five days after the explosion. At the boilers on the east side of the coal-drawing shaft two men were found, one, a fireman, had been engaged at the boilers, and the other, a wagonwayman, had probably been resting near him. Both these men were burnt, and had been subjected to some violence. The fireman was dead when found, the wagonwayman was alive but died within six hours of being brought to the surface. Flame would probably issue from the boiler fires at the fire hole at the time of the explosion, and may have burnt the fireman.

At the Lawson's way end a deputy overman was found at a lamp station, where he was waiting for his men, and where he had been left by the last person who came out of this part of the pit before the explosion. His safety lamp was blown down and was found near him. This official, together with three others, descended some time before the night shift workmen in order to examine the working faces in respect to ventilation; after this examination they repaired to the lamp stations to meet their respective workmen.

At the Middle North way end were found two boys and a deputy overman. The boys were in a recess where they were probably waiting for the night shift men. The deputy overman was at a lamp station waiting for his men. He was buried under a fall of stone.

In the Middle North stables a horsekeeper was found, under a fall of stone, at a point where he was probably engaged in the ordinary course of his work. At the Low North way end, two men were found buried under a fall of stone at the place where they had been working. One of their lamps was blown down and was found near them; the other lamp was not found, it was probably buried under fallen stone.

At the face of the Low North nine men were found; some of them had moved a few yards from the places where they had been working, leaving their lamps, which had been extinguished and were found hanging in their working places; these men were burnt but not mutilated.

In the undisturbed length of the main road were five men (including a deputy overman at a lamp station) who had moved up to 9 yards after the explosion; the position of these men will be more particularly described.

On the Narrow Board haulage road two men were found at the place where they had been working; their lamps were blown down. On the Right Hand haulage road a deputy overman was found buried under a fall of stone; he had probably been coming out to meet his men after an examination of the working face.

The victims outside the field of the explosion were the two explorers, who perished from after-damp in the return air road near the shaft, having descended after the explosion. Eight workmen and the master shifter, or official in charge of the pit, at the face of the Middle North had been traversed by a gust of air, which had extinguished their lamps, but they had not been injured or burnt by the explosion. They had, with one exception, moved out in the dark about 200 yards, leaving their lamps, before being struck down by after-damp.

Four workmen in the Hitch North had been traversed by no force or flame, nor had their lamps been extinguished; they were found on the Hitch North haulage road with their lamps. They had left their working places and had moved a considerable distance after the explosion. The oil of some of their lamps was exhausted.

There was no evidence that up to the moment of the explosion any alarm had been felt by workmen in any part of the pit. Any movement that had taken place was such as would probably occur after the explosion.

It will be noted that the four deputy overmen are assumed to have examined the parts of the pit under their charge previous to the entry of the night shift workmen. Had they, during their examination, found anything defective they would probably not have been where they were found.

In fixing the point of origin, it is necessary to consider all the places where there was a light or flame of any kind. These were—all the workmen, each of whom had a lamp, and two of them were using gunpowder; the boiler fires and the coal on fire in a flue at the shafts.

Near the shafts, as shown on Plan 1, are two roads only (through the troubles east of the shafts) into the district affected by the explosion. One of these roads, the return air way, was unaffected by the explosion, and all indications of direction showed that the explosion had passed to the shafts by the other road, the main intake; any light or flame about the shafts may, therefore, be dismissed as an origin of the explosion. The next light, passing in-bye, was the safety lamp of a deputy overman, at the Lawson's way end; he had clearly been traversed by the explosion passing to the shaft. The next lights were a group of three, the safety lamps of the deputy overman and two lads at the Middle North way end. The explosion clearly passed them going to the shaft. The horsekeeper, the master shifter, and eight workmen in the Middle North had each a safety lamp. The horsekeeper was buried under a fall of stone caused by the explosion passing into the Middle North off the main road; he could not, therefore, be selected as a point of origin. The master shifter and the eight workmen in the Middle North had not been traversed by any explosion; they were none of them burnt, nor was there any burning near them; they had, with one exception, moved some distance after the explosion, which was arrested, passing to them in two directions, viz.:—by the stables on the Middle North haulage road, and by the return air road between the Low North and Middle North. The next lights passing in-bye on the main road were the safety lamps of two shifters at the Low North way end. These men had been traversed by great force, and they were burnt. A force, coming from in-bye, had struck tubs as described within three or four yards of them. They were exposed to the full force of the explosion, and were buried under stone which fell on them at the point where they were working. There was no reason for selecting the lights of these men as points of origin. The next lights were the safety lamps of the workmen in the Low North way, nine in number. The explosion had clearly passed up the Low North haulage road to these men, and flame had extended to the face, as evidenced by the burning of the men, and by coked dust on the timber. It was quite clear that the explosion had passed to the face of the Low North way, off the main way, both by the full and empty way of the Low North, and beyond the junction of the full and empty way, by the single road constituting the Low North haulage road. Passing in-bye, over the undisturbed portion of the main road, four men were working in the Hitch North, into which no explosion had passed. These four men were not burned or injured in any way, and had moved out some distance with their lamps after the explosion and had perished from after-damp. They cannot be selected as points of origin. Two shifters on the Narrow Board haulage road had safety lamps, and had been traversed by the force of the explosion, the explosion having evidently passed in-bye to them.

A deputy overman on the Right Hand haulage road was traversed by the explosion and buried under a fall of stone. The explosion passed in-bye to him, and his safety lamp cannot be selected as the point of origin.

There remain now for consideration the five men in the undisturbed portion of the main road.

It will be noticed that this portion of the main road is, where it crosses the ten yard dip trouble, one of three roads only. These three passages connect the two portions of the mine, that lying to the east and that lying to the west of the trouble. It was clear, from examination of the two return staples or pits up the leader of the trouble, that no explosion had traversed them, and the doors in the stenton in the centre of the undisturbed portion of the main road at (33) had been blown to the return on the north side. Doors leading to the return on the south side, situated in a passage a short distance down the Cross-cut haulage road at (49), had also been blown to that return. The middle of these three passages across the trouble, or the main intake and haulage road is, therefore, the connecting link. In this road the dust showed that some movement of the air had taken place along its entire length, and burning was proved in the centre of it.

The fact of this length of road escaping damage was a very striking feature, considering the great damage done on each side of it, and that it was clearly the route over which the explosion, causing the damage on each side, had passed.

The only probable hypothesis appeared to be, that the explosion had started in this undisturbed section, and developed energy, in some manner, as it passed in-bye and out-bye.

It did not appear possible, that an explosion, producing the effects observed, could pass over one of the most confined parts of the pit (in 70 yards of which there were no side openings whatever), and do so little damage, except under special conditions.

The indications of direction of force confirmed the view that the origin of the explosion lay here.

Plan 3 shows, on a scale of 20 yards per inch, the undisturbed section of the main road and the passages adjoining. The intake air ways and haulage roads are bounded by blue lines, the return air ways by red lines. The dotted blue lines show the stone drift. The places, A, B, and C, were driven in coal below the level of the stone drift, and were not connected with it. These places were stowed with stones. The place D was connected with the stone drift, and here two man-doors stood before the explosion; the first door six yards from the main way, and the second a few yards beyond. These doors were, as described, forced to the return.

The bed of coal, in which the place D was partly driven, was below the level of the floor of the stone drift, and a road, sloping down from the point E led into it. The writers frequently came out of this stenton during their investigations, and observed that in doing so they were led in-bye, the road rising on to the main way and trending in that direction. Two sections along the lines X and Y are given, also an elevation of the north side of the stone drift, showing the entrance to the place D. It will be seen that entrance to or exit from this place would be difficult from the out-bye nook.

A Cross-cut, F had been driven out of D in the coal. It was intended to sink a staple from F to a lower level. A branch from the line of rails in the stone drift was being laid into the Cross-cut, and in order to allow the rails and tubs on them to pass into the Cross-cut some side stone was being taken off at E.

The five men in the undisturbed portion of the main road were: two stonemen, engaged in removing side stone; two wagonwaymen, making the junction with the main line of rails and the line of rails to pass into the Cross-cut F: a deputy overman was the fifth, he had no connection with the work being done, but had been at a station, H, where he met his workmen, and examined their lamps when they arrived.

After the explosion one of the stonemen was found lying or leaning with his head in-bye on the stones thrown by a shot, and the remains of the drill hole were discernible in the stone above him. Opposite to this man's body, and between the rails, was a large stone, 1 foot 8 inches long, 14 inches wide, and 13 inches deep, on which the line of the drill hole was observed. It ran along the line forming the junction of what had been the lower plane of the stone, when in *situ*, with the out-bye vertical plane. This stone had fallen from above the shot, and it evidently had not been intended to dislodge any stone from where it fell. Some stone had, before resorting to the use of powder, apparently been hacked down up to a smooth horizontal parting, and the hole was drilled on this parting, which had probably been discovered by the stonemen when hacking the stone down.

Two tubs at G, on the Hitch North haulage road, were found to be partly filled with stones and partly with wagonway rubbish. Some of the stones in these tubs had probably been worked off the side at E by the stonemen with hacks, previous to preparing the shot.

It was observed that the surfaces of the big stone, with the exception of the surface which had formed part of the side of the road, and which was blackened with the remains of an old coating of dust, and the under surface, or upper plane of the parting on the line of which the hole had been drilled, were free from dust, except to a limited extent at two points. The cavity from which the big stone had fallen was equally free from dust. The stones thrown by the shot were dusted, as well as the place from which they had fallen. The new surfaces, exposed by the stones worked off with hacks, were also coated with a fresh coating of coal dust. It was evident that the big stone had not fallen until after the explosion, and after the dust raised by it had subsided. The other stoneman was found lying on the main way, about 2 yards out-bye from his partner; his head was also pointing in-bye; an empty tub was partly over his body; his head was between the wheels on the south side of the tub, and one of the wheels on the other side of the tub was against his left thigh. His face was downwards.

The position of the empty tub was abnormal. The stonemen and wagonwaymen were taking the tubs when filled to the Hitch North, and it appeared improbable that an empty tub would be placed by them on the out-byeside of the place from which they were filling stones and rubbish. The tub had evidently not been forced over the big stone. On first visiting the place it appeared that the tub must have been, previous to the explosion, on the out-byeside of where the stonemen were working.

The stonemen's tools were set to one side a short distance from their place of work, as shown on Plan 3.

A Clanny lamp, broken in two pieces, was found under the stoneman, on the stones thrown by the shot. The glass was completely smashed. The gauze, and part of the framework constituting the upper part of the lamp, were flattened. The lamp was locked. A Clanny lamp, belonging to the other stoneman, was found somewhere near, but its exact position was never proved. It was unlocked. The glass was unbroken, but the poles were slightly damaged. It was covered with oil, which had run out of the oil vessel, and dust was on the gauze, forming a paste with the oil. The oil on the gauze proved two things—first, that the lamp had been overturned and extinguished at the time of the explosion; and second, that the lamp had been closed or screwed up at the time of the explosion, otherwise the oil would not have smeared the gauze.

It was the practice of the stonemen, in firing a shot with a Clanny lamp, to unlock the lamp, screw off the top part, making the lamp an open light; with this open light to ignite touch-paper attached to the straw in the pricker hole of the shot, and then screw on the upper part of the lamp.

At the place where the shot had been fired some loose stone was hanging, which could have been taken down by the hand. In the crevices about this loose stone coal dust had been blown. When stonemen return to resume work, after firing a shot, the first thing they do is to remove all loose stone.

There was no appearance of any stone having been removed or filled up from the shot. The tub was empty.

The two wagonwaymen were found, one in a refuge hole, and the other on the main road just outside it, 20 yards in-bye from the shot. Their lamps were found in the refuge hole near them. These men had fixed the crossing plate, and were, probably, before retiring into the refuge hole, cutting, or preparing to cut, an inch or two off a rail overlapping. Their tools had been placed against the wall side.

The deputy overman had descended some time before the explosion, and he, as well as the other three deputy overmen, did this in order to examine the working places, to be occupied by the night shift workmen, before the arrival of these men, who were met at stations appointed for the purpose. One of these stations was the point H. Here was a seat, in which the deputy overman had probably been sitting at the time of the explosion; his Davy lamp was hanging to a prop near this seat, and would not be more than 3 or 4 feet from him. This lamp had been extinguished. It was locked and undamaged. A tin water bottle stood upright on a flat surface at the seat. The deputy overman was found 9 yards from the seat, and had passed in the direction of the shaft or out-bye, leaving his lamp.

Dr. Wilson, of Birtley, by the coroner's order, made an examination of all the bodies of the victims. His report on the five men in the undisturbed portion of the main road was as follows:—

"(17) William Brown, found 28th March. Burns and violence cause of death. The hair of the head and face same as No. 18; the scalp was also leathery, and covered more or less with a white powdery substance (likely mould). There was a large hole in the skull, in the right frontal region, which was produced by fracture of the bony scalp. The right arm was dislocated at the wrist; the left arm was fractured at a point a little above the wrist; both lower legs were broken, as was also the right thigh. He had evidently been subjected to extreme violence. The stockings were torn in irregular patches, but beneath, the tissues did not give evidence of having been subjected to flame, but more to violence and a succeeding high temperature."

"(18) Samuel Brown, found 28th March. Burns and violence cause of death. This body was found, with the succeeding four men,* on the 28th March. The hair of the head and face appeared at first to be entirely gone, but, on a closer inspection, short hairs of about ⅛-inch in length were discovered, covering the back of the head and neck. Brown, I am told, was a very hairy man naturally. The short hair seen was evidently *post mortem* in its growth. There was a scalp wound, 2½ inches long, but not complicating the bone. The jacket he had worn was entirely wanting in the front part of the chest, but portions remained attached under both arms, and presented very irregular margins. The boots presented no evidence of burning, nor the clothing of the lower limbs. The hairs on the legs and chest were not singed either. There was a lacerated wound, 2 inches long, on the inner side of the left thigh, which was putrefying rapidly."

"(19) Thomas Wetherall. After-damp cause of death. The hair was slightly singed where it was not covered by his cap which was on. Front teeth were loose and quite pink in appearance (a remarkable fact). Clothing not torn in any way. No fractures or dislocations. Body much putrefied."

"(20) James Walmsley. After-damp cause of death. Hair very slightly singed. Clothes unaffected. No fractures. Body pretty well preserved compared with the rest of this lot."

"(21) Joseph Greener. After-damp cause of death. Hair quite natural, not singed. Clothes untouched. No fractures. Cap on head quite firm."

It will be observed that three of the five men here were free from marks of violence. Of the other two men, one of them had been subjected to great violence, and the other to some small violence. It was difficult to ascribe this to the force of the explosion, which had not been great here, and would have been felt by all the men alike.

The probable explanation of the whole of the facts was, that the stonemen had prepared the shot, put their tools to one side, and were ready to fire it. They warned the wagonwaymen of their intention. These men placed their tools against the side, and retired with their lamps to the refuge hole, 20 yards in-bye of the shot. One of the stonemen unlocked and opened his lamp, exposing the naked flame to the current of air passing. With this naked flame he ignited the touch-paper attached to the straw, and retired with his partner into the stenton D against the door, screwing the two parts of his lamp together. The provision box lying in the stenton may have been in his hands at the moment of the explosion, and he may have placed his lamp on the floor of the place, where it was probably found. The shot exploded, the main way filled with flame, and all the lamps were extinguished at once. The deputy overman left his lamp and rushed in the direction of the shaft for 9 yards, and then fell and died. One of the wagonwaymen came out of the refuge hole on to the main road.

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* This report was apparently written before Dr. Wilson reversed Nos. 17 and 18. See remark on page 95.

The stonemen below the level of the main way were alarmed, and the upper parts of their bodies were burned by flame entering the place. They scrambled out, one of them leaving his lamp, the other carrying his lamp with him, which he probably held in his hand at the moment of the explosion. They passed out of the stenton, and were led in-bye, fell, and died from after-damp on the main road. One following the wall side reached the shot, the other by his side fell on the rails.

The tub, which had probably stood before the explosion in-bye of the shot, was forced out-bye on the rails by a current of air succeeding the explosion in a reverse direction. The tub, driven with some force against the body of the man on the rails, passed over him, as described, and inflicted the cuts.

The big stone fell some time after the explosion, and when the dust had subsided. (26 days elapsed before the bodies of these men were reached.) In falling, it broke the bones of the dead man and broke his lamp, rolling off the body on to the rails.

The position of the big stone, in relation to the tub, was difficult to understand, unless its fall occurred after the movement of the tub.

Evidence was given by persons who knew the Browns (the stonemen), that Samuel Brown lay on the stones thrown by the shot, and that William Brown was under the tub. It is probable that an empty tub, blown back over a man's body lying on the main road across the rails would, if one of the wheels passed over the head, inflict on it with the flanges a cut; and that one of the wheels on the other side of the tub, forced against his legs when lying face downwards, would inflict a cut on the inner side of the left thigh; and that a force applied to the tub capable of doing this, would probably drag the body with it, tearing off the covering of the chest. It also appeared probable that the big stone, in falling on a man's body, would break his arms and legs, and at the same time fracture his lamp. It appeared difficult, however, to reverse the causes of these injuries. Dr. Wilson knew neither of the Browns, and could not personally identify them. They had been differently named to him on his first examination, and it appeared probable that he had described the son's injuries as those of the father, and *vice versa*. The evidence of a man, who assisted in removing the bodies from the place where they lay, proved that the body under the place from which the big stone had fallen had a broken leg. As none of the bones of the other body were broken, this established the probability of the men having been wrongly named to the doctor.

The work the stonemen and wagonwaymen were engaged upon was urgent. The main road would require to be set free upon the pit starting work on the arrival of the night-shift workmen—hewers, putters, drivers, etc. These persons were waiting on the surface to descend at the time of the explosion; 9 p.m. being the time when they commenced to descend. Under the circumstances, it would be difficult to imagine why the wagonwaymen should have left their work, unless a shot was to be fired.

The loose stone hanging at the place where the shot had been fired afforded strong evidence that the stonemen had done no work at the shot after firing it.

It was urged that the stenton D was an improbable place for the stonemen to retire to after lighting the shot, for two reasons—first, the usual practice amongst stonemen is for one man to go out-bye and the other in-bye from a shot, to warn persons not to approach; second, the position taken up would be dangerous.

With regard to the first objection, there was, in this case, no reason for one of the stonemen going in-bye, as the road was already guarded in this direction by three men—the two wagonwaymen and the deputy overman. It was found that out-bye from the shot, the road being straight, a distance of more than 120 yards could be seen in that direction. The stonemen, before lighting the shot, could assure themselves that no one could approach from in-bye, and that out-bye no one was within 120 yards of the shot. There were only two persons likely to be moving along this road at the time of the explosion, one was the horsekeeper, who had been to the stables, a short distance down the Narrow Board haulage road, and had put the harness on the horses and ponies there, and must have passed the stonemen on his way to the stables in the Middle North, where his body was found. The other person was the master shifter or official then in charge of the pit. His body was found in the Middle North, and the stonemen may have been aware of his movements.

The second objection, that the position was dangerous did not appear well founded. The drill hole was fifteen inches long, and was nearly at right angles to the road. By retiring as far as the first door the stonemen would be round a corner and eight yards from the shot. It was not possible for any stone, thrown by the shot, to reach the stonemen, if they retired to the door. It is not improbable that if the stonemen had been alone, the danger of the concussion, produced by the shot, extinguishing their lamps might have caused them to retire further, but, as a deputy overman was near, they knew that they would have had no difficulty, in such a case, in relighting their lamps.

If the stonemen and wagonwaymen had been engaged at their work at the time of the explosion, the writers would have expected that the four lamps would have been found hanging at the place of work, undamaged, and the gauzes free from oil, like the deputy overman's lamp. They would also have expected a movement, out-bye from the place where they were working, would have been evident, as in the case of the deputy overman.

The fact of the two stonemen both lying with their heads in-bye was difficult to understand, except upon the assumption that they had come out of the stenton D.

The writers conclude that a shot had been fired in the centre of the undisturbed portion of the main road, at the moment of the explosion, and this being the only source of naked flame, they assume that it was the point of origin of the explosion.

In order to account for this explosion on the assumption that it was caused by fire-damp and air, the greatest difficulties arise at every step. Thus, it is necessary to account for the presence of fire-damp in large quantities on the main intake air way, for its presence on some of the branch intakes, and its absence on others. No single source of fire-damp could account for such a state of things.

To account for fire-damp, in sufficient quantity, on any of these roads, it is necessary to assume some extraordinary occurrence—such as had never been observed before, and of which there was not a trace of evidence.

It is necessary to account for the absence of alarm amongst the workmen scattered at different points over these roads, or otherwise, it is necessary to assume that the roads had simultaneously and instantaneously been invaded by fire-damp from unknown sources.

Almost equal difficulties present themselves if it is assumed that there was even so small a quantity as one per cent. of fire-damp in the air on the roads over which the explosion extended. It would be necessary to assume the point of issue near the shaft, as it is difficult to conceive a comparatively small issue backing against a large current of air. It would be necessary to assume it entering the air with great regularity, for if it had come off in greater quantity, at one time than at others, it would have been observed on the lamps of the workmen, and could not have failed to attract their attention.

It would, under any circumstances, be pure assumption, as no source of gas was known near the shafts. 32,000 cubic feet of air per minute passed into the district of explosion, and it would require an issue of 320 cubic feet of fire-damp per minute to give one per cent. of gas in the air.

The difficulties in the way of accounting for this explosion by gas are so great that the occurrence must be considered inexplicable, unless we turn to coal dust. There was coal dust in abundance on the roads over which the explosion extended, and although, after the explosion, owing to peculiar circumstances, there was no large quantity at the point of origin, yet the writers are of the opinion, that before the explosion there would be sufficient dust at hand here to account for its initiation in the absence of any gas whatever.

The coal at Usworth, in the district of the explosion, even in the whole or first working, was very dry and dusty, and when water appeared it was from the floor of the seam. Singing rarely accompanied the issue of gas from the freshly exposed coal.

The explosion was confined to the major portion of the intake air roads, and the working face of the Narrow Board, Cross-cut, and Low North districts. The whole of these roads were dusty; and coal was hauled, by means of steam and compressed air engines, over the greater part of them. The return air roads were undamaged, and free from coal dust. The damage was entirely confined to the haulage roads.

The vicinity of the downcast shaft was wet, owing to shaft water. There was a slight dropping of water near the air crossing, a short distance out-bye from the Middle North. The bottom, and part of one side of the stone drift, was wet, and there was an issue of water at the face of the Narrow Board. These were the only natural sources of water in the field of the explosion.

For 67 yards out-bye, from the point of origin, was the wettest part of the main road, and this circumstance appeared, at first sight, to render it unlikely that any quantity of coal dust could exist here.

On Plan 3 is shown the leader of the ten yard dip trouble, crossing the stone drift. At this leader, on the south side of the road, a small feeder of salt water issued, and trickled down the side; no flow of water could be observed, but the side of the drift was wet for 8 yards from the leader; the whole of the wet side was covered with a paste of coal dust to the depth of 3 or 4 inches, and this wet dust could be taken off in handfuls. The water, after reaching the bottom, was almost entirely confined between the rails where it stood in small pools. This wetness continued up to within two yards of the shot, the water then found its way into the stenton D, and the main road beyond was dry. The north side of the drift, the top, and south side, with the exception of the 8 yards next the leader, were dry. The space between the rails and the side of the drift was damp, and this dampness extended a few inches up the side at some points, more particularly at one or two places, where the hauling rope appeared to have surged.

The sides and top of the drift, being in stone, were more or less rugged, the remains of an old coating of dust were visible both on the sides and top after the explosion, and a considerable quantity of dry dust was on all the parts of the drift clear of the water.

A current of 26,700 cubic feet of air per minute passed down this drift, and the tubs were hauled up it by the compressed air engine at the Middle North. The coal being dry and dusty there would be a quantity of coal dust blown out of and from the tops of the tubs while in the drift, and some would lodge on the sides and top. The conditions were favourable for the deposition of a large amount of coal dust on the upper parts of the drift, and the writers, speaking from experience of drifts, under similar conditions, have no doubt that the higher parts of this drift would be clothed with a thick deposit of fine dry coal dust of the inflammable nature already described. This dust would be readily shaken into the air by the concussion of a shot. It would be hanging to the top and sides, all the ledges would support it, and the tremor communicated to the stone by the shot would cause the dust to fall off. Part of this dust would be shaken off by the concussion of the shot, and the rapid movement of the air accompanying and succeeding the explosion would dislodge most of the remainder. Some would appear to have been carried out-bye, and the writers think it probable that a large quantity of the dust observed in the stenton D, would be thrown in from this drift. All the dust falling on the wet bottom would be lost as dust.

The deposit of dust, probably existing on the upper parts of this drift, would be the result of several years growth under unvarying conditions. It would be swept off at the time of the explosion, and a small portion only would re-settle, hence the appearance of the drift, as regards dust, after the explosion, would be very different to its appearance before that event.

It was urged that the passage of men and horses, and the shaking of the "cow" (an iron bar attached to the last tub of a set of full tubs, to prevent them running back in case of a broken rope or chain), would cause splashing, and wet the whole of the drift. There was no appearance to lead to the supposition that any splashing had reached the sides of the drift, and none could have reached the upper parts. The writers do not think there is any reason to doubt that there had been sufficient dry coal dust in this drift to account for the origin of the explosion.

Observations, with the wet and dry bulb thermometer, were taken at Usworth after the explosion, and are given on page 17. The readings at the top of the stone drift and 4 yards out-bye from the leader, were: dry bulb, 69½ degs. F.; wet bulb, 63½ degs. F. At the shot, or about 2 yards in-bye of the wet bottom, they were: dry bulb, 69½ degs. F.; wet bulb, 63½ degs. F. The air was as dry after passing the wet bottom as on reaching it.

The shot fired appeared to have been an overcharged shot. The drill hole was 15 inches long, nearly at right angles to the road, pointing slightly out-bye, and its axis was level. The big stone had been loosened by the powder cutting upwards, or acting in a direction not intended. The stone thrown by the shot was in small pieces, and great shattering appeared to have taken place. This would increase the concussion, and the comparatively short hole was favourable to the production of flame. The hole was drilled nearly midway between roof and floor. The area of the drift at the shot was 33 square feet, the height being 5 feet 6 inches, and the width 6 feet.

It will be noticed that it was concluded, that while lighting the touch-paper attached to the shot, one of the stonemen used the bottom part of his Clanny lamp as an open light, and, as he afterwards screwed on the upper part, no explosion can have resulted from this naked flame; and the writers conclude that, when the shot was lighted, the pit was in its ordinary state.

It was suggested that gas might have been present in the stenton D or Cross-cut E (Plan 3). The roof of these places was below the level of the main road, and there was a free outlet to a higher level,* and the writers do not think it possible to account for the presence of a gas lighter than air here.

The writers conclude that the concussion of the shot filled the air with dust; this was accompanied, or immediately followed, by an issue of flame, which caused an ignition of the dust, and results followed which will be discussed hereafter.

Having dealt with the origin, the writers will follow the explosion to the shafts first, and then in the contrary direction.

The full force of the explosion appears to have been attained on reaching the top of the stone drift; and from here, by the main road to the shaft, a distance of 2,170 yards, no increase or diminution of force was noticeable. The absence of dust, owing to the presence of moisture, arrested the explosion at the shafts.

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* See Sections along lines x and y, Plan 3.

It made four side excursions on its road to the shaft:—

1st.—It passed to the face of the Low North. This road was very dusty on the bottom. There may have been some dust on the upper parts of the road before the explosion, but probably not much, as the coal was led by horses against a very small current of fresh air. It probably passed to the face of the Low North, mainly by the bottom dust. A short distance up the Low North road it blew out the door in the travelling way, and flame passed into this road in this direction, and probably off the main road further out.

2nd.—It passed up the Middle North to the stables. The quantity of dust on the upper surfaces of this road would probably be limited, as the coal was led out of the Middle North by horses passing against a feeble current of fresh air. At the stables the bottom was damp, caused by the urine from the horses and ponies, and more dampness was caused by two large water tanks, out of which the horses and ponies drank, scattering some water in their vicinity.

3rd.—It passed a short distance along the Barmston abandoned way.

4th.—It passed a short distance along the Lawson's road. This road was a horse road, and the coal was led against a feeble current of fresh air. There was a considerable quantity of dust on the bottom, but it was not probable that there would be much dust on the upper parts before the explosion. The bottom dust was stony, and this appears to have arrested the explosion.

Passing from the shot in-bye, the first branch road was the Hitch North haulage road. This was reached by the explosion before it had attained its full force. Flame had passed a short distance down this road, but no force sufficient to cause any disturbance. The coal on this road was hauled by a compressed air engine against a small current of fresh air. The roof stone had not been taken down, and there was little timber set in the road. The conditions were not favourable to the deposition of much dust on the upper parts of the road, and it was proved that water, led from the face of the Narrow Board, had been poured in large quantity on this road, near its junction with the main road, shortly before the explosion. The water ran down the road for 80 yards, and then passed through a stopping to the east. These facts account for the explosion being arrested in this direction.

The coal on the Narrow Board haulage road was led by engine power, against a current of air equal to 23,700 cubic feet per minute, as far as the Hitch North air way, and equal to 13,700 cubic feet per minute beyond that point. There would be dust both on the upper parts and floor. The explosion passed to the face of the Narrow Board, and on its arrival there, would appear to have passed round the workings to the north, and returned across the road, as evidenced by indications left at (39) and (44). The full force of the explosion was manifested a few yards down the Narrow Board, from its junction with the Cross-cut haulage road, and this force appeared to continue almost to the face, a distance of 880 yards. Near the face signs of burning, in the shape of deposits of coked dust, increased in number, and the force decreased.

At the junction of the Hitch North air way with the Narrow Board haulage road the current of air divided into two main splits. The explosion had not passed along the air way; this road was not used as a haulage road, and its consequent freedom from coal dust did not permit the explosion to traverse it.

Returning to the junction of the Narrow Board and Cross-cut haulage roads, and proceeding along the latter, the full force of the explosion was attained a few yards from the junction, and continued nearly up to the face of the Cross-cut, a distance of 960 yards. A side excursion being made along the Right Hand road.

The coals from the Cross-cut were hauled from the point where the Right Hand road left it by engine power, beyond this it was a horse road.

The following analyses of dust and coked dust, from the field of the explosion, were made by Dr. Bedson, of the Durham College of Science, Newcastle-on-Tyne. The specimens were collected on the 4th April, 1885, or 33 days after the explosion :—

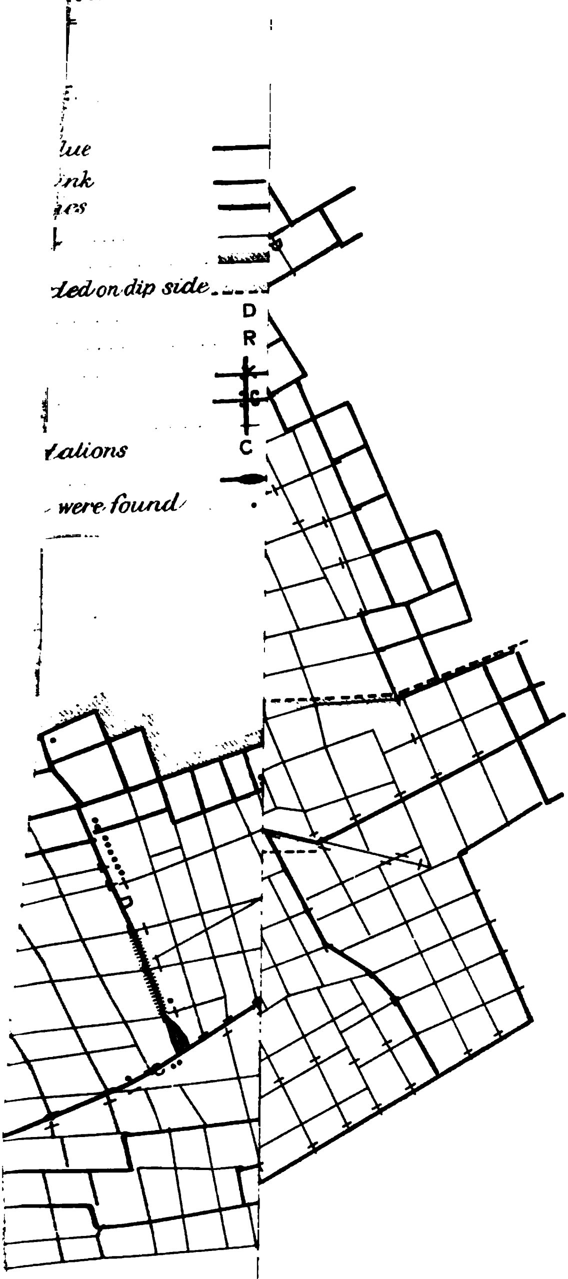
	Moisture and Volatile Matter. Per cent.		Moisture. Per cent
1. Coal dust from the floor near the shaft end of the stone drift	28·70	...	3·06
2. Coal dust from the air pipes in the stone drift ...	24·81	...	3·14
3. Coal dust from the floor of the Cross-cut haulage road	30·16	...	2·25
4. Coked coal dust from the travelling way between the Middle and Low North	20·41	...	3·70

Specimen 2, from the flanges of the air pipes in the stone drift, had a feeble coherence, and may have been slightly coked.

Y, PLAN Nº

er Inch.

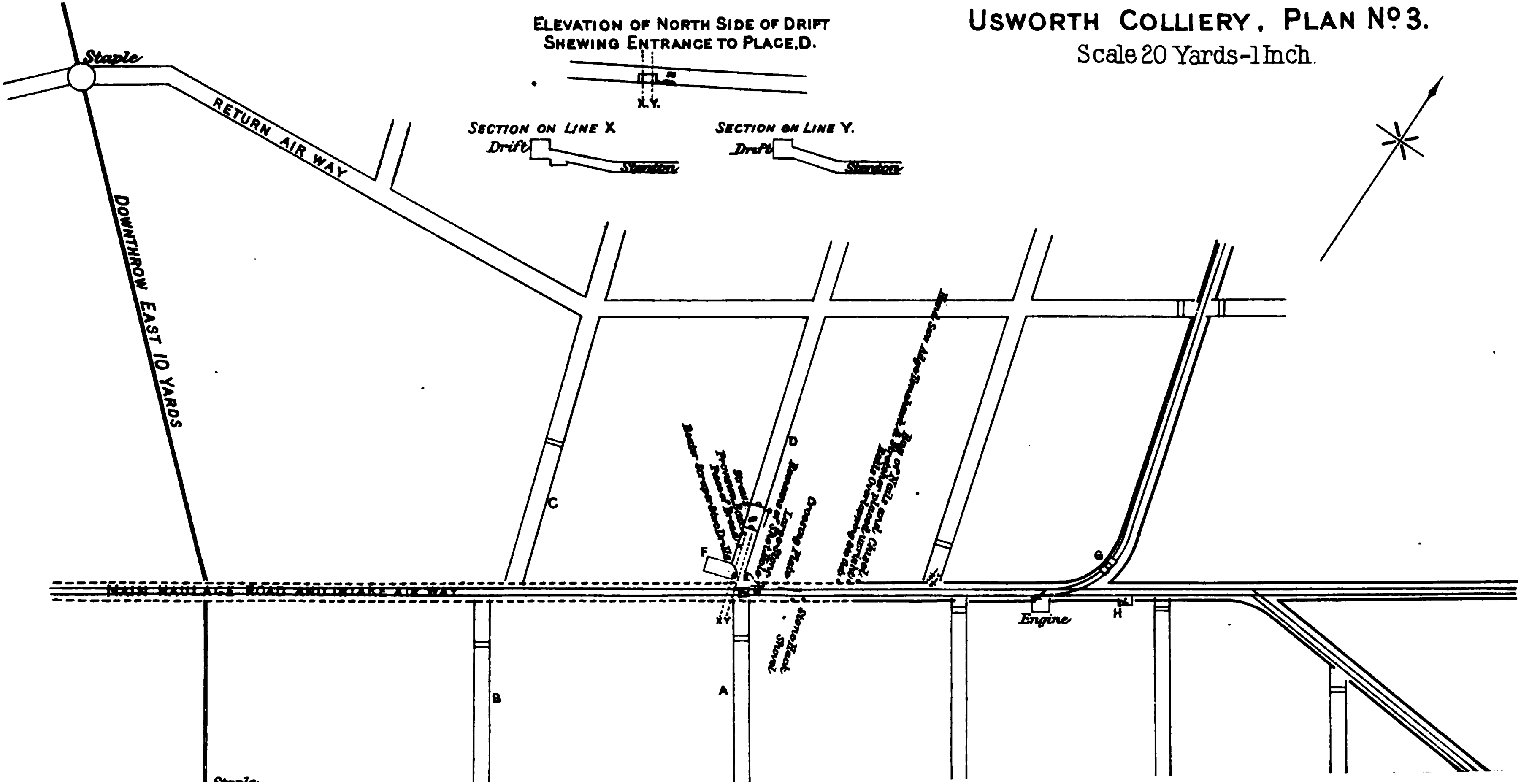
85.



Andrew Reid Newcastle.

USWORTH COLLIERY, PLAN No 3.

Scale 20 Yards-1 Inch.



Dr. Bedson analysed some upper dust from an engine haulage road in Washington Colliery, adjoining Usworth Colliery, with the following result:—

Moisture	2·5
Volatile matter	24·5
Fixed carbon (by difference)	57·8
Ash	15·2
	100·0

It contained 1·69 per cent. of sulphur. Its temperature of ignition lay between 190 degs. and 200 degs. (374 degs. and 392 degs. F.)

GENERAL REVIEW OF THE EXPLOSIONS.

Some striking features of these explosions may be pointed out.

In the Whitehaven explosion, coal dust could have played no part, but a large volume of gaseous mixture, which was known to exist before the explosion, must have been ignited, probably by a defective safety lamp.

The effect of this explosion was strictly limited, so far as violence was concerned, to the immediate vicinity of the explosive mixture. The violence or force of the explosion was less than in any of the Durham explosions. The flame had not extended 50 yards from where the explosive mixture had been before ignition. The workmen, in the field of the explosion, had all been under some alarm before the explosion, and, after it, had moved about 100 yards, one of them escaping alive. Their bodies exhibited no signs of the severe burning common after explosions in dusty pits. No signs of burning were observed except on the bodies of the victims. The explosion had extended along the return side of the brattice.

The five Durham explosions all present the following features.

In the absence of a knowledge of the danger of coal dust they could not have been expected. No accumulations of gas were known to exist, approaching in quantity what would be necessary to cause the wide-spread destruction, nor were such accumulations considered possible.

In all the five explosions the downcast shafts were damaged. At Trimdon Grange, Tudhoe, West Stanley, and Usworth the explosions did not cross or pass the downcast shafts; they were wet shafts, and the roadways in their vicinity were damp. At Seaham, the explosion crossed the downcast shaft, and extended far beyond it. This shaft was dry. In the four wet shafts the damage was limited to a few yards above the plane of the explosion, the dry shaft was damaged for more than 80 yards above the plane of the explosion.

In all cases, the violence and flame of the explosions were confined to those roads on which there was much coal dust. The greatest extent and amount of violence was on the intake and haulage roads, or between the downcast shafts and the caution boards or lamp stations, where gas could be least expected, and where naked lights were used daily.

In those cases where the explosions extended into the working faces less violence was apparent, but more evidence of burning in the shape of coked coal dust.

In no case was the return air way the route by which an explosion passed from one part of the pits to another. The explosions did not extend indifferently by all accessible routes, but, in passing from one district to others, were confined to the intake and haulage roads. On these roads was the fresh air entering the mine and much coal dust. The return air ways carry off all the gas made in the mine, but are free from coal dust.

The return air ways were unaffected at Seaham, Tudhoe, and Usworth, and were affected only to a very limited extent at Trimdon Grange and West Stanley, next those parts of the working faces over which the explosion had extended, and where the dust in them was chiefly coal dust, and where coked coal dust was observed after the explosions.

Intake air roads, such as the two travelling roads at Seaham, and the air way to the Hitch North district at Usworth, over which no coals were led, and which were comparatively free from coal dust, escaped.

In many cases the explosions were arrested at places where the haulage roads were wet or damp. The most marked examples were the North Main Coal at Seaham, the Cross-cut way at Trimdon Grange, the Shieldfield and No. 6 ways at Tudhoe, and the Middle North and Hitch North ways at Usworth. In all these cases, the air passing along the intakes which escaped, was common with or taken from currents passing along other intakes over which the explosions did extend. In several cases the explosions were arrested before reaching the face on horse roads, where the dust was largely mixed with stone dust. This was the case in the South way of No. 3 Pit at Seaham, and, probably, the Lawson's way at Usworth.

The explosions passed in every case towards the goaves; that is, whenever the course of an explosion was traced, the doors, stoppings, and movable bodies were blown towards, and never from, the goaves.

In no case did the explosion ascend or descend vertically, so as to extend the explosion on other planes. The direction of a passage, whether vertical or horizontal, would not influence the extension of an explosion of a gaseous body. Little coal dust collects in shafts or staples, so that flame supported by it will be checked in them.

In all the five Durham explosions there was no evidence that, up to the moment of the explosion, any movement had taken place amongst the workmen indicative of alarm.

We have then to consider the possibility of some mixture of fire-damp and air, in any given area, exploding and carrying its effects instantaneously over certain roads only, not expanding equally on all sides, but passing in a most capricious manner over the haulage roads only. This is difficult to conceive.

Or we have to consider the roads passed over as already containing, in themselves, the elements of explosion. If this were due to fire-damp and air the issue of fire-damp must be assumed from some source, and it does not appear conceivable that it should extend itself over one particular set of roads only, missing out other roads equally available. While this issue, of what would have to be an enormous volume of fire-damp, is going on no alarm is felt by any of the workmen, some of whom were using naked lights.

The only possible explanation appears to the writers to be that the roads traversed by the explosion contained elements of explosion of such a character as not to alarm the workmen, and these elements could only be coal dust and air, with a small percentage of fire-damp added in some parts.

The Seaham, Tudhoe, West Stanley, and Usworth explosions were simultaneous with the firing of shots in stone, and the flames of these shots are concluded to have been the means of ignition. In these cases the explosion took place when the pits were occupied by repairers and stonemen, the only time when the operations of the mines allowed the shots to be fired.

At Trimdon Grange the explosion was probably initiated by a small explosion of fire-damp and air, and in this case the pit was occupied by the ordinary workmen.

In three of the cases, Seaham, Tudhoe, and Usworth, the shots were fired on a main intake air road, in stone, and, passing the points where the shots were fired, were currents of air of 61,000, 23,000, and 26,000 cubic feet per minute. In one of these three cases the shot had been ignited by a naked flame. The writers are of opinion that the air in these three cases would be practically free from fire-damp. At West Stanley, a stone shot had been ignited by a naked flame at the working face, in a place containing much dust, and the air in this case would contain a small percentage of fire-damp.

In the four cases where the point of origin is assumed to have been a shot, there was a marked absence of disturbance near it; in the three cases where the shot was fired on a main intake, no timber was displaced for from 50 to 75 yards on each side. Where the shot was fired at the face, no timber was displaced for 80 yards from it. None of the shots were blown out shots—one was evidently an over-charged shot.

At Trimdon Grange, where the explosion is supposed to have been originated by a small explosion of fire-damp and air, the absence of damage at the point of origin was not marked.

It is well known that gunpowder is largely used in coal mines, and it would appear probable that, if in one case a shot causes an explosion, these disasters should be of more frequent occurrence, but an examination of the conditions under which gunpowder is used will help to explain this apparent anomaly.

Gunpowder is used at the face of workings—

In coal,
In stone drifts and staples.

Near the face and on the in-byeside of the engine planes it is used

In taking down top stone,
,, ,, up bottom stone,

so as to make roads available for the passage of horses, and these roads sometimes become engine planes.

In all the above cases there are usually no deposits of dust approaching in character those on the upper parts of old haulage roads.

Between the shafts and the engine landings the roads are completed, and gunpowder is rarely used on them; when it is used it is generally at points where the haulage road is above or below the level of the seam, and is altogether in stone, and it is then used in making refuge holes, removing side stone, so as to obtain access to the coal, or in enlarging the road. Thus the shots at Usworth and Tudhoe were fired at points where probably a shot had not been fired since the road was completed as a haulage road. At Seaham, the shot was for the purpose of enlarging a refuge hole; and it may be stated that on the 25th October, 1871, an explosion took place at Seaham Colliery, which was simultaneous with the firing of a shot in the stone near the point where the shot was fired in the explosion under consideration. Moreover, during the year 1872, on the firing of a stone shot near the same point, an explosion was caused, which, happily, did not spread.

None of the shots assumed as points of origin were blown out shots. A blown out shot is one in which the gunpowder blows out the stemming or tamping, in the drill hole, and does not throw the stone. The gases and flame from the combustion of the gunpowder all escape at the mouth of the drill hole. Where the resistance offered by the stemming and the stone to be thrown is nearly equal, they may give way together, and in such a case flame will issue from the drill hole. When the drill hole is short, and the length of the stemming consequently limited, an issue of flame is probable. There is always flame at the place where the powder lies, and a variety of conditions will determine the issue of flame into the air and its amount. It may depend to a large extent on the position of the dust, whether a larger quantity of it will be disturbed and thrown into the air by a blown out shot, or by a shot throwing its burden.

The writers think it possible that the shock communicated through the stone to adjacent surfaces will be greatest when the shot is not blown out; on the other hand, the rush of gases into the air will be greatest and more concentrated when the shot is blown out. In one case the energy of the gunpowder expends itself in moving and shaking solid stone, in the other in moving the stemming in the drill hole and the air outside it.

If there is a quantity of upper dust hanging to the stone and timber, and heaped up on the ledges, a shot doing its work may be more likely to throw this dust into the air than a blown out shot, and a small issue of flame might complete the conditions necessary for its inflammation.

If the dust is on the floor the shock of a shot doing its work would not disturb it to any considerable extent; the rush of gases from a blown out shot, directed downwards, would be more likely to throw it into the air.

The shots fired at Seaham, Tudhoe, and Usworth Collieries were all by the side of, and at right angles to, old haulage roads, with stone surfaces; they were about midway between roof and floor. The tremor communicated to the adjacent stone and timber would dislodge and throw into the air coal dust of the finest and most inflammable character. The air currents had high velocities, which would favour the extension of the flame by the dust.

The shot fired at West Stanley Colliery was under different conditions, and at a place where the presence of any upper dust was improbable.

The direction of the drill hole in this case could not be determined, and we are left to conjecture what the exact conditions were which led to the inflammation of the dust. There would be some fire-damp in the air, and there may have been coal dust in the stemming of the shot.

Blown out shots are sometimes referred to as being in themselves capable of causing an explosion on a limited scale, and of carrying flame to distant points, frequently burning men who had retired to places where they considered themselves safe from any possible effects of the shot. That is to say, gunpowder placed in a drill hole blows out the stemming, and causes explosive results and burning a considerable distance from the drill hole. The writers have often heard of examples of this in coal mines, but never in metalliferous mines, where gunpowder is largely used; thus the experience of the writers in metalliferous mines in the North of England, including the Cleveland ironstone mines, and the Cumberland and Lancashire hematite iron ore mines, has never furnished them with an example of the kind; and Dr. C. Le Neve Foster, one of H.M. Inspectors of Metalliferous Mines, in answer to a query on the subject, says, in a letter dated 18th January, 1886:—"I have never heard of a blown out shot doing a considerable amount of damage in a metal mine. The phrase in use at metal mines is that the charge 'blows out the tamping.' No cases of men being burnt by flames, which penetrated to points previously considered safe, have ever been reported to me." It appears to the writers that effects produced by blown out shots in coal mines, and, by some, wholly attributed to the powder, must be caused by some agent other than the gunpowder, otherwise the same phenomena would be observed wherever it is used.

It is found that coal dust is always present when flame extends far from a blown out shot, and is sometimes accompanied by fire-damp.

In three of the four explosions where the origin is referred to a shot, inflammation of the coal dust is assumed to take place on a main intake, in the absence of any gas other than the merest trace, and in one inflammation of the dust is assumed to take place at the face of a working place where some fire-damp would be present in the air. This inflammation continued as such, on the main intake, for from 50 to 75 yards in each direction, and for about 80 yards from the shot at the face. Some change then took place, and the further combustion was attended with violence, which continued in all the explosions up to their limit, except where the workings at the face were traversed, and here great violence was not observed, but more signs of burning were apparent, possibly owing to the difference in the character of the dust.

What is the reason of the change from inflammation, unattended with violence, to inflammation with violence, the writers can only conjecture. It is possibly owing to the compression of the air in front of the inflamed dust and air mixture by the expansion of the air behind it, from the heat evolved. The combustion of the dust taking place in air so compressed would be assisted, as Mr. Galloway has pointed out,* by the heat evolved during compression, and it is possible that in compressed air even at ordinary temperatures, dust would burn more readily.

There appears to be some probability that at the point where ignition of the dust first takes place, the passage may not be completely filled with flame, thus at Usworth it was observed that in one direction from the shot the two wagonwaymen and the deputy overman were not much burnt, and in the other direction some dry rope, like tow, attached to the fence protecting the air pipes at the bend, and on the side opposite to the shot, showed no appearance of having been subject to flame.

After the explosion was fairly established, conditions quite different to the ordinary conditions of a colliery would exist, which apppeared to be sufficient to insure the continuance of both flame and violence over the whole of those roads containing an uninterrupted supply of coal dust. These conditions would be :—(1) A wave of air preceding the explosion, and filling the air in the roads with coal dust. (2) Flame following instantly into compressed air charged with dust.

The writers think it would be almost impossible to assume that the whole of the main intakes over which the Durham explosions extended contained fire-damp in any appreciable quantity. At Seaham it would be necessary to assume the gas coming down the shaft, or three separate issues to take place about the time of the explosion on the three main roads diverging from the shaft.

At Tudhoe, where the air in the East and West Pits came direct from the surface by separate downcast shafts, it would be necessary to suppose two distinct issues of fire-damp.

At Usworth the air had passed no working places before reaching the shot, and could not be supposed to contain any fire-damp, beyond the merest trace.

At West Stanley some fire-damp would be present in the air where the shot was fired, but no appreciable quantity could be assumed on the main intakes.

At Trimdon Grange fire-damp was probably present in the landing, but on the main intakes it would be practically absent.

The result of experiments in boxes of limited length and area, and under conditions, and with dust differing widely from that probably present at the explosions under review, has led to the opinion that fire-damp must always be present in definite quantities. It will be observed, too, that in those cases where the explosions are concluded to have originated in the absence of any appreciable quantity of fire-damp, that much damage was not apparent until inflammation had continued for a considerable distance. It would appear that with boxes, unless gas was present, inflammation alone could be expected.

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* See *Nature*, Vol. 33, page 366.

When some of the working faces had been traversed by the explosions, as was the case at Trimdon Grange, West Stanley, and Usworth, the evidence of force was much less at these points than on the intake and haulage roads. The timber supporting the roof in the working faces was not disturbed to any considerable extent, while on the intake and haulage roads it was swept out for long distances. At the working faces deposits of coked dust were abundant, while their absence on the haulage roads was marked.

The reason of these differences may be the different conditions which exist in these roads and passages. In the following examination of some of these conditions, the return airways, along which the explosions did not extend, with the exceptions already stated, will be included.

The intake and haulage roads contain the freshest and coolest air, travelling generally at the highest velocities, and the air on these roads will not contain more than a possible trace of fire-damp.

The working faces give off fire-damp, which will be present in the air passing along at less velocity and higher temperature. This air will also contain the results of respiration and combustion from the men, horses, and lamps it has passed over.

The return air roads contain, in the air traversing them, all the gas issuing from the working face, and from abandoned parts of the mine, and also the results of respiration and combustion. The air travels in them at velocities varying greatly and depending on the number of roads open. The temperature of the air in them is higher than on the intakes, but lower than at the working face.

The intake and haulage roads contain both upper coal dust and bottom coal dust. The working faces contain bottom dust only. The return air roads are generally practically free from coal dust.

The intake and haulage roads are confined at the sides by stoppings of varying strength, and by doors. The working faces present more open passages in direct connection with each other. The return air roads are not so confined as the intakes, but more so than the working faces. The air on the intakes is usually drier than that at the working face or in the returns.

The presence, on the intake and haulage roads, of fine coal dust of a particular character, may possibly be the cause of the greater disturbance on these roads, and the absence of coked dust may be due to this dust not readily coking. The greater confinement to which the explosion is subject on these roads may also contribute to the greater violence.

The following table shows the number of fatal explosions in the collieries in Durham, Northumberland, and Cumberland since the year 1873, and the number of deaths supposed by the writers to be due to fire-damp and coal dust respectively :—

Year.	Number of Explosions	Deaths caused by Fire-damp.	Deaths caused by Coal Dust.	REMARKS.
1873	1	1	...	
1874	2	2	...	
1875	4	5	...	
1876	4	4	4	Wheatley Hill.
1877	2	2	...	
1878	4	5	...	
1879	1	1	...	
1880	2	1	164	Seaham.
1881	0	...	...	
1882	7	7	124	Trimdon Grange, Tudhoe, and West Stanley.
1883	1	2	...	
1884	0	...	...	
1885	1	...	42	Usworth.
Totals...	29	30	334	

In the foregoing table it is supposed in two cases—a small explosion at Wheatley Hill Colliery, and the explosion at Trimdon Grange Colliery—that an explosion of fire-damp was the source of inflammation of the dust, and it is assumed that the person whose light ignited the gas was, in each case, killed by an explosion of gas. The remaining lives lost by these two explosions are ascribed to coal dust. At West Stanley Colliery it is more difficult to state the principal agent to which the initiation of the explosion was due, as some gas would be present, although probably not sufficient to cause explosion in the absence of dust. The two combined, ignited by the flame of a shot in the stemming of which there may have been coal dust, are assumed to have initiated the explosion, which continued along those roads on which dust lay ; and dust is assumed to be the leading agent, and the loss of life is ascribed to it. Coal dust alone, or combined with possible traces of fire-damp, is assumed in three cases to be the fatal agent, viz., at Seaham, Tudhoe, and Usworth.

THE AFTER-DAMP.

The after-damp encountered in the Durham collieries after the explosions appeared to possess very deadly properties. At Trimdon Grange, Tudhoe, and Usworth it caused the death of persons who descended after the explosions; and in many cases the explorers suffered severely from it. It appeared to contain some gas other than those usually met with in mines under ordinary conditions, or such as are generally supposed to result from the combustion of fire-damp.

The gases met with in the ordinary working of coal mines are fire-damp, or light carburetted hydrogen, and stythe, or carbonic acid gas. Sulphuretted hydrogen is occasionally observed. Fire-damp indicates its presence by its effect on the lamp, and is found next the roof, when pure. It does not appear to exert any prejudicial effect on the human system, even when respired to a considerable extent. Stythe is usually met with in shallow pits. In air mixed with it a lamp or candle burns dimly, and it is found near the floor. Miners frequently work in air so mixed with stythe as to render it necessary for them to place their candles close to the roof, and as far from the face as possible, and this not for an hour or two, but for days, without feeling any directly bad results. The writers have frequently examined parts of mines, where there was great difficulty in preserving a light, without feeling any ill effects. Sulphuretted hydrogen is readily detected by its smell. The constituents of after-damp are generally supposed to be carbonic acid gas, nitrogen, and water vapour, the two latter being non-poisonous. The presence of any of these gases in the air in such quantity as to be quickly harmful to life would be at once shown by their effect on lights.

After the explosions in Durham, it was evident that some other gas was present in the air; the lamps burnt brightly, and when they gave no indication of the presence of any kind of gas, men were overpowered. The writers have been affected under such circumstances on entering parts of the pits where ventilation had not been restored, and have been present when persons lost consciousness, and had to be carried back into purer air, and yet no indications were given by the lamps.

It was observed that the oil in some of the lamps of victims, who had perished from after-damp while waiting for rescue, was exhausted, as if the lamps had not been extinguished by the after-damp which killed the bearers, but had burnt until the oil was consumed.

At Usworth, an attempt was made to arrive at some knowledge of the gases present after an explosion in a dusty mine. On the 7th March, a stopping to cut off the air from a fire was erected in the intake at A, Plan 1. On the 9th March, a stopping was erected in the return near the same point. On the 13th March, a plug was removed from a pipe through the stopping in the return, and some of the gases which issued from the pipe was collected, by one of the writers, in two glass vessels.

Dr. Bedson, Professor of Chemistry at the Durham College of Science, Newcastle-on-Tyne, kindly furnished the following analysis :—

Carbonic acid gas	4·54	vols.
Carbonic oxide	2·48	„
Light carburetted hydrogen	8·68	„
Oxygen	7·23	„
Nitrogen	76·80	„
	99·73	„

The stoppings being to the rise of a large extent of workings, fire-damp was likely to be found near them. The presence of a fire beyond might have had some influence on the production of the carbonic acid and carbonic oxide gases.

The writers, knowing the poisonous nature of carbonic oxide, think it probable that the after-damp owes much of its extremely deleterious effects on the human system to the presence of this gas.

It appears, from experiment, that carbonic oxide does not indicate its presence in air by any effect on the flame of a lamp, until present in volume exceeding 10 per cent.

POPULAR IDEAS ABOUT EXPLOSIONS.

There are some views as to the course explosions take, which are very generally held, and often advanced, not as scientific reasons, but as based on observed facts, more or less common to all large explosions.

Expressions, which are proverbial in the mouths of miners, will now be considered, and it will be found they support the coal dust theory. The writers conceive that the old miners put forward these views as accounting, in an empirical manner, for phenomena that were unexpected. One of the commonest of these expressions is that an explosion always "faces the wind," or "travels against the fresh air." The origin of this saying probably is that, in many cases, in earlier times, explosions, started at the working face by an ignition of fire-damp, extended from the point of origin as a dust explosion, traversing the main intake, the road on which the dust lay, to the downcast shaft, the only course open to it under such circumstances being, therefore, to face the incoming air.

In all the cases under review, except Whitehaven, the explosions extended for long distances, both with and against the current of air. It seemed clear that the direction in which the air was travelling had no influence on the course of an explosion after it was once started. Cases have been observed which make it appear probable that a dust explosion, starting in a main intake, has a tendency at first to go with the air, and not against it. This, however, is only observed at the point of origin.

In order to account for the exhibition of force on the intake air roads and its absence in the returns, it is sometimes said that the explosion travels along the former route because the air is purer there, and better able to support combustion, or that "the gas seeks the fresh air." As a matter of fact, in all the collieries described, the difference between the fresh, or intake air, and the return air was very slight as regards the power of supporting combustion; and the principal impurity in the return air was probably fire-damp. The return air is warmer and moister, but lights burn well in it, and all the functions of life are properly performed. One class of workmen, the wastemen, work altogether in it. The writers do not think the difference in the air would have any effect in preventing an explosion extending along the return air roads.

Again, it is said, the sectional area of the return air roads is smaller, that they are more tortuous than the intakes, and so offer more resistance to the passage of the blast. This is true to a certain extent; but, on the other hand, the return air roads in some of the cases described were for long distances straight, and as large or larger than the intakes. But yet they were not traversed by any explosion.

Then, again, it is argued, that the explosions extend to the shafts because they "act as outlets." This idea has no doubt arisen because the majority of large explosions pass to the bottom of the downcast shafts. The reason of the explosions so doing, may be the fact, that there is generally a line of dusty road extending to these shafts, and not because the shafts act as outlets. The site of the shaft is often the limit of an explosion, owing to its immediate surroundings being damp. Many large explosions have not reached the shafts.

An idea appears to be held that an explosion, caused by the combustion of fire-damp contained in a limited area, can extend for very great distances along the air ways of a mine, for distances apparently out of all proportion to the assumed quantity of explosive mixture.

The fact of explosions so often extending to the downcast shaft along the fresh air roads has probably caused this view to be held. No one has conceived that these roads were in an explosive condition along their entire length, so that, in the absence of any other means of accounting for the extension of the explosion, it seemed necessary to suppose that a gas explosion at some distant point had so extended itself.

The writers have investigated almost all the explosions of fire-damp which have occurred in the North of England during the past thirteen years; these explosions, causing death or injury to from one to four persons, in no case produced effects greater than might have been anticipated from the known or probable amount of gas present.

The Whitehaven explosion, a pure gas explosion, is partly introduced to emphasise this aspect of the question.

In the five Durham explosions, which are regarded as explosions caused by coal dust, there were many marked examples of the sudden cessation of force, within short distances of places where the supply of coal dust ceased, and where proofs of the existence of flame were visible.

It is common for witnesses in explosion inquiries to speak of the blast passing for long distances from some point of origin, along a road not in an explosive condition, this essential condition not appearing to be considered necessary; in other words, that the force developed at some point, by the combustion of gas and air, had extended itself along confined roadways for long distances, without any addition and without any diminution of violence. The writers deem it of the utmost importance to attempt to set this view aside. It appears to them that the resilient properties of columns of air, in the narrow passages of a mine, are such, that no great force can be exerted at any considerable distance away from where actual expansion due to combustion takes place. A moderate force may be exerted some distance away, but violence sufficient to cause death, or displace timbering, does not appear to extend many yards from the actual explosion.

If the latter view be correct, it is not sufficient, in order to account for explosions such as those described, to say that an outburst of gas has taken place, and has exploded near the outburst. Before the explosion takes place the gas must be mixed with air to the explosive point over the roads along which the explosion extends. It must be explained how it was that certain roads traversed by the current of air after passing the source of gas became explosive, while other roads, traversed by currents from the same source, were untouched by the explosion. It must be explained how the gas backed against large currents of air for long distances, and how all this fouling took place without attracting the notice of men in the currents.

Such witnesses, having fire-damp and air in view only, must assume that these things need not occur before the mines are brought into the state necessary to render the large explosions under notice possible.

Finally, it must be remembered, that in all the five Durham explosions, it is a pure assumption to suppose that any sudden outburst took place.

The following examples from the explosions described may be advanced, as bearing on the above question of the transmission of force.

At Seaham, the men in the South way in No. 3 Pit, into which the explosion extended as far as the air crossings, were not killed, nor injured in any way by the explosion, nor were their lamps extinguished. They were about 400 yards beyond the limit of the explosion, and the road was open from this point to where they were working. Four of these men escaped alive by passing to the shafts by the return air road, the remainder attempting to reach the shafts by the intake perished from after-damp. One of the survivors said, "We felt a heavy wind and small coal flying." The travelling roads in No. 1 Pit, and in the Maudlin, parallel to the haulage roads, and acting as double intakes, being open at both ends, and traversed by currents of air passing off the haulage roads, were not damaged, except near their junction with the haulage roads, although great disturbance was observed on the latter. The doors in the passage leading from the No. 1 Pit travelling road to the return were not moved, although the force necessary to blow down doors is not great. The workmen at the face of all the districts were not injured by the force of the explosion, all having passed out some distance. In many cases their lights were not extinguished. The portion of undamaged road near the shaft, although in the very centre of great violence, had escaped.

At Trimdon Grange the workmen in the Cross-cut district, although in the direct line of the explosion coming up from the main road, were uninjured, and no disturbance was noticeable on the Cross-cut haulage road, except to a limited extent near the junction. The timber in the horse road between the Second and Third South ways of the Pit Narrow Board district was not displaced, and the driver, horse, and tubs in this length were not injured by force.

At Tudhoe several marked examples of the sudden stop of force were observed.

At Whitehaven the effect produced by the explosion of what must have been a large quantity of explosive mixture of fire-damp and air was quite local. Workmen, within 50 yards of where combustion probably ceased, were not injured. A gust of air was felt a mile away.

At Usworth the explosion extended to the downcast shaft with great violence, and flame had arrived there. Its effects died out rapidly in the vicinity of the shaft in all directions. Two men at the smaller downcast, 40 yards away, escaped alive. A pony in the loose box near was not injured or burnt. Men at the lower level, 18 yards below, were not seriously injured. The explosion, arrested at the Middle North stables, had extinguished the lights of the men at the face, but had not injured them, as they all, with one exception, had passed out a considerable distance in the dark. They would be approached by the explosion from two directions—from the face of the Low North, and from the stables in the Middle North. The undisturbed portion of the main road, though in the direct line of the explosion, had escaped damage. This road was one of three, and all had escaped violence. Both the Hitch North haulage road and air way had been traversed by no force. The lights of the workmen at the face of the Hitch North would appear not to have been extinguished.

In all the five Durham explosions, although great disturbance was observed on the haulage roads, the return air ways, where free from coal dust, were undamaged, except to a trifling extent, by force passing from the intakes. This force died out very rapidly at all these points. At many places doors, stoppings, and air crossings, easily moved, would have allowed passage of force, but no such passage was observed. It is difficult to conceive how a force, capable of causing great disturbance more than a mile away in one direction, should not, in other directions, pass more than 40 yards, except that, in the one case, a vehicle existed which was wanting in the other.

In considering the facts stated, the writers are of opinion that the explosions having been arrested by want of fuel, the damage had ceased with the flame. A gust of air of considerable force would extend some distance beyond the flame, but no blast sufficient to do extensive damage; and the force of the gust of air would appear to diminish rapidly as the distance from the flame increased, lights not being extinguished 300 or 400 yards away.

The fact of the passages of a coal mine being filled with air, an elastic fluid, preserves those passages out of the field of an explosion from damage.

It has been the custom to speak of phenomena such as those described, either as examples of the erratic nature of an explosion, the vagaries of which follow no natural laws, or to get over the difficulty by saying that the district, or part of the pit not penetrated by the explosion, was a *cul de sac*, notwithstanding the facts that the road was open into it and another road led out of it, and that, in some cases, men rescued stated the ventilation was in its ordinary state at the time.

CONDITIONS IN MINES LEADING TO EXPLOSIONS.

Some general conditions concerning explosions in coal mines will be considered.

The initiation of an explosion may be due to an ignition of fire-damp, to the ignition of a cloud of coal dust, or to the ignition of a mixture of fire-damp and coal dust. The flame causing ignition may be that of an open light used for lighting, or of a fire for producing ventilation or steam, or of a fire accidentally caused; or it may be from gunpowder or other explosive, or from a safety lamp.

Fire-damp.—Fire-damp, owing to its lightness, rises to the highest points, and until diffusion takes place, is found in such places; otherwise it behaves as air, and passes along mixed with the ventilating current. A naked light is a common source of its ignition.

Fires underground, whether used for producing ventilation or steam, are placed in such positions and under such conditions, as to render it improbable that fire-damp, in such quantity as to be inflammable, can reach them. Fires accidentally caused in mines producing fire-damp may cause explosions. Second explosions, which sometimes occur, are probably initiated in this way. Flame of gunpowder, or other explosive, is probably a rare cause of the ignition of fire-damp present in the air current (in the absence of dust). Before shots are lighted in fiery mines an examination is made for gas, and men know they would risk their lives if they fired a shot where gas could be detected in the air current. It is very improbable that in the interval between the examination and the explosion of the shot, the air passing over it would become inflammable, from gas alone. Gas liberated by a shot, or issuing in a jet near it, is not infrequently ignited by the flame, and burns at the point of issue. A shot fired near a goaf where a proper examination cannot be made, or near a cavity in the roof which has not been examined, may occasionally ignite an accumulation of fire-damp. When a shot is blown out, the probability of it igniting gas is increased, by reason of the increased distance to which the flame is carried; and when coal dust has been used in the stemming of a blown out shot, the flame extends still further, and so increases the possibility of igniting gas.

The flame of a safety lamp may cause ignition of fire-damp outside it from any one of four causes: (*a*) If the lamp is defective. A defective or injured lamp of any construction may be no safer than an open light. (*b*) In the case of many of the safety lamps now in use, such as the Davy and Clanny lamps, if they are exposed in an explosive mixture of fire-damp and air travelling above a certain velocity. It has been proved by repeated experiments that such lamps will ignite gas outside them, when exposed in an explosive current travelling at from 6 to 10 feet per second. (*c*) Some lamps of large internal capacity, or those so enclosed by solid casing as to increase the effect of internal explosion on the gauze, when manipulated in a particular manner, in a stationary mixture of fire-damp and air, will cause the ignition of gas outside them by the explosion of gas within them. This fact was only recently discovered by M. J. B. Marsaut, a French mining engineer, who describes the process by which it can be effected.[*] (*d*) It is possible for some lamps to pass flame to gas outside them, if they are subject to a momentary wave or gust of air such as may be caused by the firing of a shot,[†] or by attempting to blow out the flame,[‡] while they are surrounded by an inflammable or explosive mixture of fire-damp and air. In the cases (*b*), (*c*), and (*d*) it is not the flame of the safety lamp which directly ignites gas outside the gauze; the flame of the lamp first ignites gas inside the gauze, then usually going out; the ignited gas inside the gauze eventually communicates with the outside gas.

It may be pointed out that some of the tests to which safety lamps are submitted in experiments are much more severe than any which they are likely to encounter in practice. The writers believe that many explosions attributed to the ignition of fire-damp by the flame of safety lamps have been due to other causes.

Coal dust.—Coal dust, under ordinary circumstances, does not exist as a dense cloud in the air of a mine, and is not carried along by the ventilating current, except to a very limited extent. To become inflammable in the air the coal dust must be present in the form of a dense cloud.

An open light is a rare source of ignition of a dust cloud. Examples of this are stated to have occurred in some mines in France,[§] where the circumstances were favourable to the production of a dense cloud of coal dust above an open light. Accidents caused by the ignition of a cloud of coal dust by open lights on the surface are recorded, both in this country and on the Continent.

Fires underground, used for producing ventilation or steam, are so situated that it is very improbable that they should cause the ignition of coal dust in the air. It appears possible that under favourable conditions a fire accidentally caused might do so. If the conditions were such that the fire caused a current of air, so strong as to carry a cloud of coal dust over it, or if the fire caused a fall of stone or timber so as to produce a dust cloud of sufficient density, the dust might be ignited.

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[*] See "Miners' Safety Lamps," Vol. IX., Midland Institute of Mining, Civil, and Mechanical Engineers. Translation of J. B. Marsaut's paper by T. Carrington.

[†] See "Safety Lamps and Shot Firing," by W. Galloway, North of England Institute of Mining and Mechanical Engineers, Vol. XXIV.; also Proceedings of the Royal Society, 1874.

[‡] See letter by W. Galloway, "Colliery Guardian," 27th August, 1886.

[§] See paper "On the Influence of Coal Dust in Explosions of Fire-damp," by M.M. Chauselle and Desbief, published in "Bulletin de la Société de l'Industrie Minérale de Sainte-Etienne, 1875." Translation by W. Galloway, published in "Iron," January 26th to March 23rd, 1878.

The disturbance produced by the explosion of gunpowder ensures, under some conditions, the production of a dust cloud, and the accompanying flame is a common source of its ignition.

There appears no reason to suppose it possible that a dust cloud may be ignited by the flame of a safety lamp.

Coal dust, not suspended in the air, is sometimes ignited by the flame of a shot, or by an open light. This class of ignition may be compared with that of fire-damp, burning, as a jet, at the point of issue.

Fire-damp and coal dust.—It has been shown experimentally that a cloud of coal dust in air, containing, according to Galloway,* less than 1 per cent., and according to Abel,† from 2 to 2½ per cent. of fire-damp, is readily inflamed at ordinary temperatures and pressures, by an open light.

The presence of a porous dust, even of a non-inflammable nature, will determine the ignition of fire-damp and air mixtures, which are not inflammable in the absence of the dust.

The flame of gunpowder, passing into a cloud of coal dust, in air containing a small proportion of fire-damp, will be more likely to cause ignition than in the absence of fire-damp.

There appear, at present, no grounds for stating that the presence of coal dust, in air containing fire-damp, adds to the probability of the flame of a safety lamp igniting the mixture.

The extension of an explosion, however initiated, may be caused by the continued ignition of fire-damp, coal dust, or a mixture of the two. It frequently happens that a gas explosion is confined, owing to the absence of dust, to a gas and air mixture. It cannot be so positively asserted that an explosion is entirely confined to dust, because the practical absence of gas, although it may be probable, cannot be positively proved by an examination after the explosion, as can the absence of dust in some fire-damp explosions.

It has been stated that an inflammation of coal dust may cause a considerable explosion by bringing about the ignition of fire-damp and air mixtures. This is possible, but it appears to the writers that the greatest danger is the converse of this, that the explosion of an accumulation of fire-damp may cause ignition of dust. In all the explosions which have been described, except Whitehaven, they were confined to those parts of the pits where there was a plentiful supply of coal dust, and, in all cases, passed from one part of the pits to others, along roads on which there was the least probability of fire-damp being present in the air. So far as can be gathered, from accounts of other large explosions, the same holds good.

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* Transactions of Royal Society, Vol. XXIV.

† "Report on the Results of Experiments made with Samples of Dust Collected at Seaham Colliery," by F. A. Abel, C.B., F.R.S.

Fire-damp issues from the strata in mines, either normally as a regular flow, or abnormally as a sudden outburst. It exists either mixed with the air current and passing along with it, or as an accumulation, more or less pure, in cavities in the roof, in the open parts of goaves, or in abandoned and unventilated passages.

Fire-damp existing as an accumulation, sometimes flows into the air current with more or less suddenness, as when a fall of roof-stone takes place near it, which may cause a rapid displacement of fire-damp, followed by an equally rapid return. When pent up by water, and under pressure, fire-damp sometimes comes off in gluts, a phenomenon known in mining as a "water blast."

A lessened atmospheric pressure causes fire-damp, existing as accumulations in unventilated places or goaves, to flow into previously uncontaminated parts; it also increases the flow of fire-damp issuing from gullets and fissures in the strata. At some collieries, where large areas of abandoned workings and goaves are adjacent to the return air ways, it is found that, during a rapid fall of pressure, fire-damp issues from them in such quantity, as to show on the flame of a safety lamp in the air in some of the returns. It has not been proved, and it is not probable, that the normal flow of fire-damp from solid strata is influenced to an appreciable extent by natural variations of atmospheric pressure.

Sudden outbursts of fire-damp from the strata are rarely met with, so far as the writers can learn, except while mining new ground. Fire-damp issuing as a sudden outburst will probably displace the air in the vicinity of the outburst. It will always have a tendency to pass from the point of issue with the air current, rather than against it. The extent to which it may back against the current will depend upon circumstances, such as the amount of gas given off, compared with the amount and velocity of the air currents, and the rise or dip of the passages in the vicinity.

A study of the phenomena accompanying the issue of large outbursts of gas shows that*—(*a*) After the outburst evidence can almost always be found as to the point of issue. (*b*) During the issue workmen near are alarmed, and retreat with their lamps. (c) In many cases the lamps are extinguished by the gas, and sometimes workmen are suffocated.

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* See "On Instantaneous Outbursts of Inflammable Gas in the Coal Mines of the Belgian Basin," by A. G. Arnould, Royal Chief Engineer of Mines at Mons. Translation in Vol. IX. of the Transactions of the Midland Institute of Mining, Civil, and Mechanical Engineers, by T. Mitchell; also "Narrative of Sudden Outbursts of Gas in Collieries Working the Barnsley Thick Coal and the Silkstone Coal in the neighbourhood of Barnsley," published by the Midland Institute.

The results of the ignition of what were stated to be large outbursts of gas, in the probable absence of coal dust, do not resemble the results described in the five Durham explosions.

The issue of fire-damp, either from the strata or from open parts of the mine, is most likely to take place at or near the working face or in the return air ways; and, from the place where it issues, it is most likely to exist in the air passing towards or along the return air ways. It is in the return air ways, therefore, that there is the greatest probability of an explosion of fire-damp on a large scale. The fact that such explosions are not experienced renders it improbable that fire-damp plays the principal *rôle* in coal mine explosions.

Mixtures of fire-damp and air are only explosive, at ordinary temperatures and pressures, within certain comparatively narrow limits, which have not yet been accurately determined. It appears probable that all mixtures, between those containing 5 per cent. and 20 per cent. by volume of fire-damp, are inflammable. A mixture containing about 10 per cent. by volume of fire-damp is the most explosive. The compression and consequent heating of mixtures of fire-damp and air (not inflammable at ordinary temperatures and pressures), by an explosion, will render them inflammable. A large volume of pure fire-damp existing in a mine is not available for the transmission of flame; it requires first to be mixed with air.

The occurrence of coal dust in mines has been described.

It would appear probable that an excess of coal dust is favourable, rather than otherwise, to the propagation of flame in air laden with it. An excess of coal dust often exists for long distances on the haulage roads, the air passing along them containing no fire-damp, other than a possible trace. trace. It was on these roads that most force had been exerted, and on which the greatest extent of violence was observed in the explosions described.

Another condition, which appears to have considerable influence on the development of flame in air laden with coal dust, is the velocity with which the air moves, and the velocity of the air is usually high on the haulage roads.

Experiments witnessed by the writers, in 1880 and 1883, called attention to these conditions. The apparatus used was a box 36 feet long, and 1 square foot in sectional area, placed horizontally, and provided with windows for observation of the passage of flame. One end of the box was open to the air, and here the coal dust was introduced; the other end was inserted in a chimney, the draught from which produced a current of air through the box. The velocity of the air was regulated by perforated shutters next the chimney. Flame was produced by firing by electricity half an ounce of compressed gunpowder, placed in the box near the open end. Coal dust collected from the upper parts of underground roads, and from screens on the surface was used. The former appeared to be the most inflammable.

It was found that with velocities equal to, or exceeding, 1,500 feet per minute, the flame frequently extended right through the box, or more than 30 feet, and that the greater the amount of dust held in suspension in the air, the greater was the certainty of the flame extending through the box.

The effect of igniting the dust by burning gas jets was tried. The jets were 20 feet from the chimney end of the box, and consumed five-sixths of a cubic foot of lighting gas per minute, as tested by a meter. Dust was added at the open end of the box, and was carried by the current over the burning gas jets. The flame was gradually lengthened as the velocity of the current was increased, until at a velocity of about 750 feet per minute, the flame extended to the end of the box. A longer box was set on fire by flame from coal dust in air, travelling between 1,500 and 2,000 feet per minute. In this case, the box was filled with flame for nearly 50 feet. In both cases, the flame extended as far as the apparatus permitted. The flame could be kept burning as long as the supply of dust was kept up.

In these experiments, the velocity of the air current necessary to carry the flame as far as the apparatus allowed, was greater than the velocity of the currents usual in the main intake air ways of collieries; on the other hand, the experimental boxes were of much smaller sectional area than the area of those roads. This larger area, capable of containing a body of flame from thirty to sixty times greater than the boxes, would probably enable the flame to extend further with lower velocities of current; and if such an ignition of dust was well established in the air ways of a mine, it would probably develop in such a manner as to become self-propagating, both with and against the air current of the mine. It may be that the high velocity of the air current in the experimental boxes is only necessary, in order to enable it to carry a dense enough cloud of dust, as the dust was only introduced at one point; on a dusty road in a colliery, any sudden shock or violent movement of air would cause dust to rise from the ground and fall from the roof and sides.

Nothing that could be called an explosion attended the inflammation of the dust in these experiments. In the explosions described and attributed altogether to coal dust, no evidence of explosive violence was observed for a much greater distance from the supposed points of ignition than the length of the experimental boxes. Whether the change from inflammation without violence, to inflammation attended with explosive force, is altogether due to the increased volume of flame causing cumulative force, or to some change in the nature of the inflammation, is a question requiring further study.

The formation, and subsequent ignition of a cloud of coal dust in a mine, may practically be referred to two causes:—An explosion of a mixture of fire-damp and air; the explosion of gunpowder in the form of a shot.

An explosion of fire-damp and air on a haulage road, in the presence of upper dust, would readily produce a cloud of dust, and a small volume of explosive mixture, would be likely to initiate an explosion of dust in such a situation.

At the working face, where an explosion of fire-damp is much more likely to occur, the conditions are not so favourable for the ignition of dust. There is no upper dust, and it would require a more considerable disturbance to raise a cloud of dust from the floor. It is quite possible that a small explosion of fire-damp might take place, even in moderately dusty workings, without igniting a cloud of dust in the air.

When a shot is fired on a haulage road where there is upper dust, a quantity of it is thrown into the air, whether the shot is blown out or not, and there is always the possibility that the cloud so formed may be ignited by flame from the shot.

The dust on the upper parts of haulage roads is accompanied by, and partly owes its deposition to rapid currents of fresh air, and the current of air aids in the development of a moving cloud at the time the shot is fired.

When a haulage road is driven in stone, it is, for motives of economy, made no larger in area than is necessary, and the velocity of the air is consequently often higher at such points than when the road is driven in coal and is of larger sectional area. The places on old haulage roads, where shots are usually fired are where the road is altogether in stone. Conditions favourable to the accumulation of upper dust, and to the ignition of a dust cloud, in the absence of fire-damp, by the flame of a shot, therefore often exist at the places where shots (rarely fired on such roads) are most likely to be required.

When shots are fired at or near the working face the air may contain a small percentage of fire-damp unknown to the person who fires the shot, but in other respects the conditions are much less favourable to the production and ignition of a dust cloud. The coal dust is confined to the floor, and is not so pure and fine, nor of the readily combustible character of the dust on the upper parts of haulage roads.

It would appear probable in order to bring about the ignition of a cloud of coal dust raised from the floor of a working place—(*a*) that the dust must be more thickly deposited than is usual, even in dry and dusty mines; (*b*) that the axis of the drill hole, if produced, should reach the floor within a short distance of the mouth of the hole, or that the hole be drilled near the floor; (*c*) that the shot must be either blown out, overcharged, or a heavy shot in stone. An examination of the circumstances, in cases where a shot at the face has been stated to have caused an explosion, appears to show that one or more of these conditions always existed.

It may be specially noted that the great majority of shots in coal at the working face are near the roof, and the probability of their raising and igniting a cloud of dust, even if blown out, is small.

REMEDIAL MEASURES.

That coal dust has some influence in colliery explosions is now generally admitted, and the more the subject has been investigated the more is its importance manifested.

Very few persons are perhaps prepared to go so far as the writers, whose opinion is, that explosions may not only be "intensified" or extended by coal dust, but that they may be entirely supported by it.

Although the correct view is of course an important matter, its bearing on remedial measures is fortunately not so great as might at first sight appear. If the influence of coal dust is admitted to be of so grave a character as to necessitate measures for dealing with the danger, the means employed must be the same, whichever view is held. Until recently no effectual means have been taken. Watering the roadways in dusty pits has been practised for many years, probably as much for convenience and cleanliness as for any other reason; but this watering has been totally inadequate. In all the collieries in which explosions have been described the main haulage roads were said to be watered, but the amount of dry dust on them after the explosions showed that the watering had been of little or no avail. The method usually adopted is to draw water tubs after the engine set, or by horses, the tubs having holes in them for the water to run out on to the road. At best this only wets a part of the floor, and its effect is often not perceptible after a few hours.

If the conclusion as to the origin of the Usworth explosion is correct, it appears that where upper dust exists, the complete absence of bottom dust, owing to permanent dampness of the floor, will not prevent the extension of an explosion by means of coal dust past the wet road.

If the conclusions, as to the origin of the explosions at Seaham, Tudhoe, and Usworth are correct, it appears that the firing of shots on old haulage roads, where there is much dry coal dust, is attended with great danger. It must be remembered that gunpowder is much less frequently used on such roads than in other parts of the pits.

The Trimdon Grange explosion points to the danger of explosions of fire-damp, however small, where they may communicate with and be extended by coal dust.

The West Stanley explosion shows the danger of blasting in dusty workings, where an imperceptible amount of fire-damp may be in the air.

The great loss of life in these disasters largely arose from the highways of the collieries having been traversed by the explosions. These roads were filled with after-damp, and rendered impassable by falls of stone, and the after-damp penetrated the return air ways which were not damaged, so that even, in the numerous cases where the explosions had not injured persons at the working faces, they could not escape. At Seaham Colliery, four workmen, led by an experienced old pitman who had escaped from some other explosions, succeeded in getting out by the return before the after-damp had rendered the air poisonous; and at Trimdon Grange, a few workmen escaped from the Cross-cut way, having only to travel a short distance of road, over which the explosion had extended, before reaching the downcast shaft.

In passing from one district to another the explosions always traversed the main intake air ways, and passed to the downcast shafts by these roads, cutting off all communication. No system of dividing the mines into separate districts averted the effects of the explosions, which passed from one district to another by the roads considered least likely.

If the haulage roads could be kept free from coal dust an explosion could not be originated on them, and they would not convey an explosion from one district to another, but might be expected to be as inert, in this respect, as the return air roads were observed to be. The great velocity of the currents of air now common in dusty pits, and necessary for the ventilation of the mines, has a direct tendency to increase the quantity of dust deposited on the roads over which coals are led.

The quantity of dust collecting on haulage roads might be reduced—(1) by reducing the velocity of the air, which may be attained by enlarging or doubling the roads; (2) by reducing the speed at which the tubs travel. The endless rope or chain system of haulage would effect this, the speed of the tubs would not then exceed 3 or 4 miles an hour, as compared with 10 to 15 miles by main-and-tail ropes. In order to prevent dust flying off the tops of the tubs, at one colliery in Durham, a spray of water is made to play upon them as they pass under it. This is said to have considerable effect. The tops of the tubs on engine planes might be protected by tarpaulin covers, one cover being made to pass over a certain number of tubs. The above measures are, however, only palliative.

The removal or efficient damping of dust on the haulage roads is not unattended with difficulty. The dust is constantly accumulating on them, and upper dust is almost peculiar to them. The sides and roof are often very irregular in contour, and much water sometimes causes the strata to disintegrate.

Dust on the bottom may be collected and sent out of the pit, and the floor kept damp by watering. In some cases where the application of water has been difficult or harmful the use of coarse salt has been found beneficial. Its hygroscopic action comes into play and causes the dust to adhere and solidify. When used in conjunction with water the effect is more lasting than when water alone is used.

Water conveyed in ordinary water tubs cannot be applied effectually, as it only wets the bottom, and, generally, only part of that. A much better method is to convey small water pipes, with cocks at frequent intervals, along the roads which require watering; with the aid of a hose a man can then thoroughly water all parts of the road.

In cases where there are special difficulties in the way of effectually removing or watering the dust on haulage roads, the mine might be divided into sections by cutting off the supply of dust at particular places. This could be done by arching a length of road, and keeping it scrupulously free from dust. The top and sides might be whitewashed occasionally, and the bottom dust removed by sweeping or otherwise. What the length of these cleansed places should be would require careful consideration—perhaps 100 yards would suffice. Bottom dust might be rendered uninflammable by an adulterant, such as sand.

The dust in the working places is almost entirely bottom dust, and although it may be quite capable of causing the extension of an explosion over a district, would be unable of itself to extend it to other distant parts of the mine; so that if the haulage roads were kept so free from dust as to be unable to conduct an explosion, each district might be considered separately with regard to dust, something in the same way as they are now considered with regard to fire-damp.

Special precautions are necessary with regard to blasting. Shots should not be fired where there is much dust of any kind, in places where there may also be a small proportion of fire-damp in the air, because even non-combustible dust has the property of causing the ignition of otherwise non-inflammable mixtures of fire-damp and air, when the proportion of fire-damp is so small as to be difficult to detect by the flame of the lamp. This action of non-combustible dust was discovered by Sir F. Abel when experimenting with dust from the South way in No. 3 Pit at Seaham Colliery, where, as has been stated, the dust was largely mixed with stone dust, and over which the explosion did not extend. If dust of any sort is present where there may possibly be a small proportion of fire-damp in the air, the vicinity in which the shot has to be fired should be specially watered. The use of dry dust for tamping should be prohibited.

The writers believe that the chief danger of shot firing in coal mines is due to coal dust. The greatest precautions have long been taken in regard to fire-damp where shot firing is concerned, and if equal precautions were taken with regard to coal dust, it is probable that the danger arising from the use of explosives would be so reduced as to allow of greater freedom in their use than would otherwise be possible. In mines free from dust, the existing restrictions as to the use of explosives might be considerably relaxed.

A more drastic remedy may be suggested. From what has been said before, it appears that the dryness of collieries depends on two causes—(1) the temperature of the mine being higher than the temperature of the air entering the mine; (2) the large volumes of air constantly circulating. Thus, a large volume of air entering the mine at 40 degs., and raised in its course to 70 degs., exercises an enormous drying power. If the air entering the mine was artificially raised to the temperature of the mine, and saturated with moisture, it could exercise no drying power, and the natural moisture of the mine would then come into play, and dry pits might become damp pits.

The objections to this proposal may be stated thus:—The expense of raising the temperature of the air, and saturating it; if the heating were effected as the air descended the downcast shaft it would oppose the ventilating power; the moist air would have a bad effect on the roof stone; moist air at a high temperature is not so agreeable to workmen as dry air at the same temperature; in the case of dip workings, (as at Usworth, where the face lay 160 yards below the shaft bottom, and the temperature of the rock at the face would be 8 degs. higher than the temperature of the rock at the shaft), air heated to the temperature of the rock at the shaft, and saturated, would rise in temperature as it proceeded in-bye and became dry.

The advantages might be, if the mine really became damp:—Large explosions, such as the five Durham explosions, would not be possible; the expense connected with the removal of dust might be avoided; shot firing might be practised with reference to the danger arising from gas only.

The operations necessary on the occurrence of serious colliery accidents are of such a difficult nature, and the investigation of explosions involves so many obscure questions, that it appears desirable to have special means for these purposes; as well for endeavouring to rescue survivors as for making the observations necessary to discover the causes of the accidents. At present everything has to be arranged and organised on the spur of the moment, under circumstances of great confusion. Few attempts are made to take intelligent and methodical observations until the opportunities for doing so are lost. All endeavours are naturally, primarily, bent on the rescue of survivors and the recovery of the bodies of the victims.

Explosions or serious accidents are not so common as to render it necessary that each colliery should be provided with all the appliances likely to be of service. For the same reason, the number of persons with much practical experience concerning them is limited.

A central institution might be formed in each large mining district, where all the necessary appliances and instruments might be kept, and a corps of experts, and volunteers from the collieries, trained in their use. A controlling staff of mining engineers and scientific men might be enrolled, who would make the arrangements necessary for the efficient service of the institution, and for the observation and recording of such facts as would appear likely to throw light on the causes of the accidents. They would hold themselves in readiness to proceed at once to the scene of an accident, and by means of relays secure the intelligent observation of everything likely to elucidate their cause, as well as endeavour to rescue survivors, and secure the safety of explorers. Rules might be drawn up for the guidance of persons assisting at or investigating different classes of accidents. Members of the institution might be delegated to attend accidents in other districts for the purpose of obtaining practical information and rendering asssitance.

HISTORICAL.

The number of fatal explosions in coal mines, and the number of deaths resulting therefrom in the United Kingdom for the last 35 years is given in the accompanying table.

Year.	Number of Fatal Explosions.	Number of Deaths Resulting.	Number of Deaths per Fatal Explosion.	Number of Persons Employed in and about the Mines.	Ratio of Persons Employed.		Remarks.
					To each Fatal Explosion.	To each Resulting Death.	
1851	98	321	3·28	216,217	2,206	673	First Mines Inspection Act in force.
1852	91	264	2·90	222,843	2,449	844	
1853	89	214	2·40	229,468	2,578	1,072	
1854	87	210	2·41	236,094	2,714	1,124	
1855	99	146	1·47	242,719	2,452	1,662	
1856	72	236	3·28	249,345	3,463	1,056	Amended Mines Act in force. Cymmer, 114.
1857	74	377	5·09	255,971	3,459	678	Lundhill, 189.
1858	70	215	3·07	262,596	3,751	1,221	
1859	70	95	1·36	269,222	3,846	2,833	
1860	70	363	5·19	275,847	3,940	759	Risca, 142.
Totals and averages for 10 years, ending 1860.	820	2,441	2·98	2,460,322	3,000	1,008	
1861	61	119	1·95	282,473	4,630	2,374	Amended Mines Act in force.
1862	55	190	3·45	291,000	5,291	1,532	
1863	51	163	3·20	299,000	5,862	1,834	
1864	59	94	1·59	307,542	5,213	3,271	
1865	64	168	2·62	315,451	4,929	1,877	
1866	71	651	9·17	320,663	4,516	492	The Oaks, 361.
1867	56	286	5·11	333,116	5,948	1,165	Ferndale, 178.
1868	44	154	3·50	346,820	7,882	2,252	
1869	48	257	5·35	345,446	7,197	1,344	
1870	56	185	3·30	350,894	6,266	1,897	
Totals and averages for 10 years, ending 1870.	565	2,267	4·01	3,192,405	5,650	1,408	
1871	52	269	5·17	370,881	7,132	1,378	
1872	62	154	2·48	418,088	6,743	2,714	
1873	44	100	2·27	512,199	11,641	5,122	Amended Mines Act in force.
1874	44	166	3·77	538,829	12,246	3,245	Ireland included from 1874.
1875	41	288	7·02	535,845	13,069	1,860	Swaithe Main, 143.
1876	42	95	2·26	514,532	12,250	5,416	
1877	45	345	7·66	494,391	10,986	1,433	Blantyre, 207.
1878	31	586	18·90	475,329	15,333	811	Haydock, 189; Abercarne, 268.
1879	35	184	5·26	476,810	12,625	2,591	
1880	28	499	17·82	484,933	17,319	971	Risca, 120; Seaham, 164; Penygraig, 101.
Totals and averages for 10 years, ending 1880.	424	2,686	6·33	4,821,837	11,372	1,795	
1881	31	116	3·74	495,477	15,983	4,271	
1882	35	250	7·14	503,987	14,399	2,015	
1883	25	134	5·36	514,933	20,597	3,842	
1884	30	65	2·17	520,376	17,345	8,005	
1885	25	341	13·64	520,632	20,826	1,527	Clifton Hall, 178.
Totals and averages for 5 years, ending 1885.	146	906	6·20	2,555,405	17,503	2,820	

It will be observed, that, while the number of explosions has steadily decreased during the period, the resulting loss of life has increased. It thus appears that the average number of lives lost per explosion has increased.

During the 10 years ending 1860 the average number of lives lost per explosion was 2·98.
" " 1870 " " " 4·01.
" " 1880 " " " 6·33.
" 5 years 1885 " " " 6.20.

During the period of 35 years the ratio of persons employed to each explosion and to each death has increased, so that the record is satisfactory in every way except as to the ratio of persons killed to the number of explosions.

The writers believe the explanation of this unfavourable feature to be as follows:—During the whole of the 35 years under review the use of safety lamps has been becoming more general, and during the last 14 or 15 years the use of explosives has been considerably restricted. This accounts for the lessened number of ignitions. In the earlier years a larger proportion of the explosions was due to the ignition of small accumulations of fire-damp in collieries producing little gas, and worked with candles, such explosions usually only causing one death. This class of collieries, usually shallow and damp, are now generally worked with safety lamps. The number of deep and dusty mines has increased during the period. In this way the proportion of ignitions in the deeper and dusty collieries has increased, and an explosion in them, however initiated, is much more serious than in a damp pit. Great precautions are usually taken in these mines with regard to fire-damp. What is now required is that efficient precautions shall be taken with regard to coal dust.

LIST OF EXPLOSIONS IN COLLIERIES IN DURHAM, NORTHUMBERLAND, AND CUMBERLAND, INVOLVING THE LOSS OF FIVE OR MORE LIVES, BETWEEN THE YEARS 1871 AND 1705.

No.	Date and Hour.	Colliery.	County.	Plane of Explosion.		Dry, Dusty, or Wet.	Lights in Field of Explosion.	Field of Explosion.	Lives Lost.	Evidence as to Coal Dust.	Remarks.
				Seam.	Depth at shaft						
					Yards.						
1	Oct. 25, 1871, 11·30 p.m.	Seaham ..	Durham	Hutton ..	510	Dry and dusty	Mixed ..	Intake and haulage road	26	Abundant; coked dust not mentioned.	Shot fired; downcast not affected; stables set on fire.
2	Jan. 29, 1869, 2·0 a.m.	Springwell ..	„	Low Main ..	259	„ „	Open lights	Face	5	Coked dust observed..	Shot fired; shafts not affected.
3	Oct. 31, 1866, 5·30 a.m.	Pelton ..	„	Busty ..	180	„ „	Lamps ..	All passages on south side of shafts.	24	„ „ ..	Fan; reached downcast.
4	Sept. 9, 1864, 11·0 p.m.	Seghill ..	Northumberland	Low Main ..	157	„ „	„ ..	Face and haulage road for 500 yards.	7	„ „ ..	Shafts not affected.
5	March 6, 1863, — a.m.	Coxlodge ..	„ ..	High Main..	190	„ „	Mixed ..	Working face	26	„ „ ..	......
6	Nov. 22, 1862, 7·0 a.m.	Walker ..	„ ..	Low Main ..	320	„ „	Lamps ..	Working face, haulage road, & return adjacent	16	„ „ ..	Shot fired in return near face.
7	Dec. 20, 1860, 8·0 p.m.	Hetton ..	Durham	Hutton ..	296	„ „	Mixed ..	Intake and haulage roads	22	Abundant	Do.; stables set on fire; downcast affected.
8	March 3, 1860, — p.m.	Burradon ..	Northumberland	Low Main ..	290	„ „	„ ..	Face and haulage roads	76	Coked dust observed..	Shafts not affected.
9	July 14, 1853, 8·0 a.m.	Wearmouth	Durham	Maudlin ..	574	„ „	Lamps ..	Face	6	.. ..	Shot fired.
10	June 9, 1852, —	Seaton ..	„	Hutton ..	510	„ „	Mixed ..	.. ..	6	.. ..	......
11	May 6, 1852, 10·0 a.m.	Hebburn ..	„	Bensham ..	320	„ „	Lamps ..	.. ..	22	Coked dust observed..	Shot fired; shafts not affected.
12	Oct. 31, 1851, 1·0 p.m.	Killingworth	Northumberland	High Main..	226	„ „	„ ..	.. ..	9	„ „ ..	Shafts not affected.
13	Aug. 18, 1851, 11·30 p.m.	Washington	„	Hutton ..	210	„ „	Open lights	Face and haulage roads	35	„ „ ..	Shafts not affected.
14	Nov. 11, 1850, 7·0 a.m.	Houghton ..	Durham	Hutton ..	232	„ „	Mixed ..	Face and haulage roads	26	"Symptoms of fire" ..	......
15	June 5, 1850, 8·30 a.m.	Usworth ..	„	Maudlin ..	300	„ „	Open lights	„ „ ..	13	"Traces of fire." ..	Shot fired; shafts not affected.
16	June 5, 1849, 6·0 a.m.	Hebburn ..	„	Bensham ..	320	„ „	Lamps ..	.. ..	32	Coked dust observed..	......
17	Oct. 28, 1848, —	Cleator Moor	Cumberland ..	Bannock ..	191	„ „	Mixed ..	.. ..	30	.. ..	......
18	Aug. 15, 1848, 12·30 p.m.	Murton ..	Durham	Hutton ..	456	„ „	Open lights	Face and haulage road..	17	Coked dust observed..	Shafts not affected.
19	June 22, 1847, 9·30 p.m.	Felling ..	„	Low Main ..	232	„ „	„ ..	Intake air road	6	.. ..	Shot fired; stables set on fire; 19 horses lost.
20	Aug. 21, 1845, 1·0 p.m.	Jarrow ..	„	„ ..	390	„ „	„ ..	Face and intake air road	39	Coked dust observed..	Reached shaft.
21	April 3, 1845, 6·0 p.m.	Killingworth	Northumberland	High Main..	226	„ „	Mixed ..	.. ..	10	Coal dust blown up shaft.	Reached shaft.
22	Sept. 28, 1844, — p.m.	Haswell ..	Durham	Hutton ..	308	„ „	„ ..	Face and haulage roads	95	Coked dust observed..	Shafts not affected.

LIST OF EXPLOSIONS IN COLLIERIES IN DURHAM, NORTHUMBERLAND, AND CUMBERLAND.—*Continued.*

No.	Date and Hour.	Colliery.	County.	Plane of Explosion.		Dry, Dusty, or Wet.	Lights in Field of Explosion.	Field of Explosion.	Lives Lost.	Evidence as to Coal Dust.	Remarks.
				Seam.	Depth at shaft						
					Yards.						
23	Jan. 18, 1844, 9·0 a.m.	Killingworth	Northumberland	High Main ..	226	Dry and dusty	Open lights	.. ..	5	.. ..	......
24	Jan. 8, 1844, 4·0 p.m.	Whitehaven	Cumberland ..	Main ..	254	.. .. ..	„ ..	.. ..	16	.. ..	......
25	Aug. 5, 1843, 4·15 p.m.	Thornley ..	„	Harvey ..	290	Dry and dusty	Open lights	Face and haulage road..	9	Coked dust observed..	......
26	April 5, 1843, 7·45 a.m.	Sheriff Hill	Durham	Beaumont ..	190	„ „	Mixed ..	.. ..	28	.. ..	Reached shaft.
27	April 19, 1841, 1·15 p.m.	Willington ..	Northumberland	Bensham ..	280	„ „	„ .	„ „ ..	32	„ „ ..	Stables set on fire; reached downcast.
28	June 28, 1839, 9·0 a.m.	Hilda ..	Durham	„ ..	286	„ „	„ ..	.. ..	51	Dust and smoke issued from shaft.	Reached shaft.
29	Feb. 18, 1839, — a.m.	Whitehaven	Cumberland ..	Main ..	190	.. .. ..	Lamps ..	.. ..	23	.. ..	......
30	Dec. 19, 1838, 9·0 p.m	Wallsend ..	Northumberland	Bensham ..	291	Dry and dusty	Mixed ..	.. ..	11	.. ..	Shafts not affected.
31	Oct. 24. 1838, —	Harrington ..	Cumberland ..	Udale ..	190	„ „	Open lights	.. ..	35	.. ..	Reached shaft.
32	Dec. 6, 1837, 9·0 a.m.	Springwell ..	Durham	Hutton ..	256	„ „	Mixed ..	.. ..	30	Coked dust observed..	......
33	Jan. 28, 1836, 1·30 p.m.	Eppleton ..	„	„ ..	343	„ „	Open lights	Face and haulage road..	20	.. ..	......
34	Nov. 19, 1835, 4·0 p.m.	Burdon Main	Northumberland	Low Main ..	185	.. .. ..	„ ..	.. ..	11	.. ..	Shafts not affected.
35	June 18, 1835, 2·0 p.m.	Wallsend ..	„ ..	Bensham ..	291	Dry and dusty	Mixed ..	Haulage roads	102	Coked dust observed..	Shot fired; reached shaft.
36	May 9, 1833, 2·0 p.m.	Springwell ..	Durham	Hutton ..	256	„ „	„ ..	.. ..	47	.. . .	Reached shaft.
37	Sept. 20, 1831, 9·0 a.m.	Willington ..	Northumberland	Bensham ..	216	„ „	Open lights	.. ..	7	.. ..	......
38	Aug. 3, 1830, 5·40 a.m.	Jarrow ..	Durham	„ ..	350	„ „	„ ..	Face and haulage road adjacent	42	Coked dust observed..	Shafts not affected.
39	Nov. 20, 1828, 3·0 p.m.	Washington	„	Hutton ..	220	„ „	„ ..	.. ..	14	Clouds of dust blown up shaft.	Reached shaft.
40	Sept. 1, 1828, —	Houghton ..	„	Main Coal ..	192	„ „	„ ..	.. ..	7	.. ..	......
41	Mar. 15, 1828, 3·0 a.m.	Jarrow ..	„	Bensham ..	350	„ „	Mixed ..	.. ..	8	.. ..	......
42	Sept. 5, 1826, 6·0 a.m.	Heworth ..	„	Hutton ..	164	„ „	Open lights	.. ..	5	.. ..	......
43	May 30, 1826, 3·0 a.m.	Townley ..	„	Five-Quarter	136	„ „	„ ..	.. ..	38	.. ..	Things blown up shaft.
44	Jan. 17, 1826, 8·0 p.m.	Jarrow ..	„	Bensham ..	350	„ „	„ ..	.. ..	34	.. ..	......
45	July 3, 1825, — p.m.	Fatfield ..	„	Main Coal ..	160	.. .. ..	„ ..	.. ..	11	.. ..	... ..

LIST OF EXPLOSIONS IN COLLIERIES IN DURHAM, NORTHUMBERLAND, AND CUMBERLAND.—*Continued.*

No.	Date and Hour.	Colliery.	County.	Plane of Explosion.		Dry, Dusty, or Wet.	Lights in Field of Explosion.	Field of Explosion.	Lives Lost.	Evidence as to Coal Dust.	Remarks.
				Seam.	Depth at shaft						
					Yards.						
46	Nov. 19, 1824, —	Newbottle ..	Durham	Hutton ..	265	Dry and dusty	Mixed ..	.. ..	11	.. ..	Shaft affected.
47	Oct. 25, 1824, —	Lumley ..	„	„ ..	152	.. .. ..	„ ..	.. ..	14	.. ..	......
48	Nov. 3, 1823, 5·30 a.m.	Rainton ..	„	„ ..	152	Dry and dusty	„ ..	.. ..	59	Smoke and fire issued from shaft.	Shaft affected.
49	Oct. 23, 1821, —	Felling ..	„	Low Main ..	204	„ „	Open lights	.. ..	6	.. ..	......
50	Oct. 23, 1821, 8·0 a.m.	Wallsend ..	Northumberland	Bensham ..	291	„ „	„ ..	.. ..	52	.. ..	......
51	Oct. 9, 1819, —	Lumley ..	Durham	Hutton ..	152	.. .. ..	„ ..	.. ..	13	.. ..	......
52	July 19, 1819, —	Sheriff Hill	„	„ ..	250	Dry and dusty	„ ..	.. ..	35	Smoke issued from shaft.	......
53	Dec. 18, 1817, —	Rainton ..	„	„ ..	148	.. .. ..	„ ..	.. ..	27	.. ..	......
54	Sept. 25, 1817, —	Jarrow ..	„	Bensham ..	350	Dry and dusty	„ ..	.. ..	6	.. ..	......
55	June 30, 1817, 11·30 a.m.	Harraton ..	„	Hutton ..	179	„ „	„ ..	.. ..	38	Cloud of dust & smoke issued from shaft.	Safety lamp introduced in 1816.
56	June 27, 1815, 4·0 a.m.	Sheriff Hill	„	„ ..	250	„ „	Open lights and steel mill.	.. ..	11	.. ..	Things blown up shaft.
57	June 2, 1815, 4·0 p.m.	Newbottle ..	„	„ ..	225	„ „	Open lights	.. ..	52	Cloud of dust issued from shaft.	Reached shaft.
58	Aug. 12, 1814, —	Hebburn ..	„	High Main ..	233	„ „	„ ..	.. ..	11	.. ..	......
59	Dec. 24, 1813, 1·30 a.m.	Felling ..	„	Low Main ..	204	„ „	„ ..	.. ..	22	.. ..	......
60	Sept. 28, 1813, —	Fatfield ..	„	Hutten ..	160	.. .. ..	„ ..	.. ..	32	.. ..	......
61	July 17, 1813, —	Collingwood Main.	Northumberland	Bensham ..	140	.. .. ..	„ ..	.. ..	8	.. ..	......
62	Oct. 10, 1812, 1·0 p.m.	Herrington ..	Durham	Hutton ..	290	Dry and dusty	„ ..	.. ..	24	.. ..	......
63	May 25, 1812, 11·30 a.m.	Felling ..	„	Low Main ..	204	„ „	„ ..	All workings	92	Cloud of dust issued from shaft.	Reached both shafts.
64	Sept. 14, 1809, —	Killingworth	Northumberland	High Main ..	228	„ „	„ ..	.. ..	12	.. ..	Did not affect shaft.
65	Mar. 28, 1806, — p.m.	„ ..	„ ..	„ ..	226	„ „	„ ..	.. ..	10	.. ..	Things blown up shaft.
66	Nov. 29, 1805, —	Oxclose ..	Durham	Maudlin ..	160	.. .. ..	„ ..	.. ..	38	.. ..	Things blown up shaft.
67	Oct. 21, 1805, —	Hebburn ..	„	High Main ..	233	Dry and dusty	„ ..	.. ..	35	.. ..	......
68	Sept. 3, 1803, —	Wallsend ..	Northumberland	„ ..	226	„ „	„ ..	.. ..	13	Burning dust observed	......

LIST OF EXPLOSIONS IN COLLIERIES IN DURHAM, NORTHUMBERLAND, AND CUMBERLAND.—*Continued.*

No.	Date and Hour.		Colliery.	County.	Plane of Explosion.		Dry, Dusty, or Wet.	Lights in Field of Explosion.	Field of Explosion.	Lives Lost.	Evidence as to Coal Dust.	Remarks.
					Seam.	Depth at shaft Yards.						
69	Oct. 11, 1799,	—	Lumley ..	Durham	Hutton ..	110	.. .. ..	Open lights	.. ..	39	.. ..	......
70	Feb. 27, 1798,	—	Washington	„	„ ..	220	Dry and dusty	„ ..	.. ..	7	.. ..	......
71	„ 12, 1796,	—	„ ..	„	„ ..	220	„ „	„ ..	.. ..	7	.. ..	......
72	April 24, 1795,	—	Benwell ..	Northumberland	Brockwell ..	130	.. .. ..	„ ..	.. ..	11	.. ..	......
73	Dec. 20, 1794,	—	Sheriff Hill	Durham	Hutton ..	250	Dry and dusty	„ ..	.. ..	Several.	.. ..	......
74	June 11, 1794,	—	Harraton ..	„	„ ..	160	.. .. ..	„ ..	.. ..	28	.. ..	......
75	„ 9, 1794,	—	Rickleton ..	„	„ ..	150	.. .. ..	„ ..	.. ..	30	.. ..	......
76	Dec. 27, 1793,	—	Sheriff Hill	„	„ ..	250	Dry and dusty	„ ..	.. ..	14	.. ..	......
77	Aug. 21, 1787,	— p.m.	Wallsend ..	Northumberland	High Main ..	226	„ „	„ ..	.. ..	7	.. ..	......
78	Nov. 3, 1786,	—	„ ..	„ ..	„ ..	226	Wet	Steel mill ..	.. ..	6	.. ..	......
79	Dec. 6, 1773,	— p.m.	No. Biddick	Durham	Hutton ..	160	.. .. ..	Open lights	.. ..	19	.. ..	Things blown up shaft.
80	Mar. 27, 1767,	— a.m.	Fatfield ..	„	„ ..	160	.. .. ..	„ ..	.. ..	39	.. ..	.....
81	Aug. 22, 1766,	—	Lambton ..	„	„ ..	150	.. .. ..	„ ..	.. ..	6	.. ..	Things blown up shaft.
82	April 16, 1766,	-	So. Biddick	„	„ ..	155	.. .. ..	„ ..	.. ..	27	.. ..	......
83	Mar. 18, 1766,	—	Walker ..	Northumberland	High Main ..	200	Dry and dusty	„ ..	.. ..	10	.. ..	......
84	April 2, 1765,	—	„ ..	„ ..	„ ..	200	„ „	„ ..	.. ..	8	.. ..	17 horses killed.
85	Dec. 1, 1761,	—	Hartley ..	„ ..	„ ..	80	Wet	„ ..	.. ..	5	.. ..	......
86	June 10, 1757,	—	Ravensworth	Durham	Hutton ..	188	.. .. ..	„ ..	.. ..	16	.. ..	......
87	Aug. 11, 1756,	2·0 a.m.	Chatershaugh	„	„ ..	160	Dry and dusty	„ ..	.. ..	4	Coal dust blown up shaft.	......
88	Jan. 18, 1743,	5·0 a.m.	No. Biddick	„	„ ..	160	.. .. ..	„ ..	.. ..	17	.. ..	......
89	Aug. 5, 1737,	4·0 a.m.	Whitehaven	Cumberland ..	Main ..	186	.. .. ..	„ ..	.. ..	22	.. ..	......
90	Aug. 18, 1708,	3·0 a.m.	Fatfield ..	Durham	——	114	.. .. ..	„ ..	.. ..	69	.. ..	"Fire came up three pits."
91	Oct. 3, 1705,	—	Stony Flat ..	„	Hutton ..	120	.. .. ..	„ ..	.. ..	30	.. ..	Things blown up shaft.

In the preparation of the foregoing list of explosions, which is necessarily very imperfect, the principal sources of information are as follows. The numbers refer to the numbers in the list:—

Reports of Inspectors of Mines, 1 to 13.
Transactions of the North of England Institute of Mining Engineers, 7, 8, and 9.
Transactions of the Northumberland, Durham, and Newcastle-on-Tyne Natural History Society, 35, 38, 50, 68, and 77.
Transactions of the Chesterfield and Derbyshire Institute of Mining, Civil, and Mechanical Engineers, 3.
Transactions of the Manchester Geological Society, 7.
Philosophical Transactions, 22 and 90.
Reports of Commissioners sent down by Government, 20 and 22.
Reports of Committees and Commissions of both Houses of Parliament on Accidents in Mines, 35, 36, 37, 50, 55, 64, and 65.
Report of Children's Employment Commission, 25, 27, 29, and 31.
"Winning and Working of Collieries," by M. Dunn, 13.
"How to Prevent Accidents in Collieries," by M. Dunn, 11, 12, and 13.
Pamphlets published in the District, containing principally the Evidence at Inquests, 7, 8, 22, 28, 35, and 63.
Fletcher on the Archæology of the West Cumberland Coal Trade, 89.
"Compleat Collier," 91.
Unpublished Accounts, 3, 8, 57, and 63.
Inquiry by the Writers of Persons present immediately after the Explosions, 1, 3, 4, 5, 6, 7, 8, 12, and 21.

The remainder of the information has been derived from newspaper accounts (either direct or from tables based on such accounts), and from inquiry made by the writers.

Through the courtesy of the Editor of the "Newcastle Daily Chronicle," one of the writers was afforded an opportunity of consulting files of newspapers extending back to the year 1764.

Where it is not stated in the list that the collieries were dry or wet, the writers have been unable to obtain any satisfactory information. The dryness of a colliery or the presence of coked coal dust, previous to a few years ago, were not stated as facts having any bearing upon explosions, but were mentioned incidentally; and the absence of information on these points does not indicate that the collieries were not dry and dusty, as the probability is, judging from their situation, that they were. Thus the collieries at Fatfield, North Biddick, South Biddick, Chatershaugh, Rickleton, Harraton, Washington, and Oxclose, situated on the banks of the Wear, and adjacent to each other, were in a district naturally dry, and probably could not have been worked in early times had there been much water to deal with.

Previous to 1816, the only lights used in collieries were open lights and the steel mill. The steel mill, introduced in the year 1760, consisted of a machine, worked by hand, by means of which a steel wheel rapidly revolved against a piece of flint, caused a shower of sparks, which did not, as a rule, cause ignition of fire-damp.

The presence of open lights in a mine, while increasing the number of explosions of fire-damp, would probably have the effect of limiting the field of such explosions.

The use of self-acting inclines was introduced underground in the year 1800.

Up to the year 1832, corves or baskets, made of hazel rods, were used for conveying coal underground. These baskets were more open than the wooden tubs afterwards introduced, and caused the accumulation of much dust on the roads. The use of corves continued in some cases for many years after 1832.

About the year 1855 haulage by main-and-tail ropes was introduced into collieries.

There is no example in the North of England of a large explosion caused by the ignition of fire-damp at a ventilating furnace. In nearly all the cases on the list, the air, after ventilating the mines, passed over a furnace at the bottom of the upcast shaft, yet this practice never appears to have caused an extensive explosion. Thus, while explosions are common on intake air roads, where gas is practically absent, the return air, laden with all the gas issuing from the working face and abandoned places, passes over a large fire constantly burning, and no large explosions result. In a paper on Mining Records, on page 327 of Vol. II. of the "Transactions of the Natural History Society of Northumberland, Durham, and Newcastle-on-Tyne," Mr. Buddle states (referring to Wallsend Colliery):—"On this day (9th October, 1785,) the air course became loaded to the firing point, and exploded at the B Pit furnace, this pit being the upcast. Fortunately, the pit was not at work at the time, and nobody was down except the wastemen, who were occupied with something or other near the bottom of the A Pit, which was the downcast. They were thrown about by the concussion (wind) occasioned by the explosion, but were not seriously hurt, and all got safely to bank."

Mr. Buddle, in his evidence before a Select Committee of the House of Commons, in the year 1835, said:—"One of the returns at Jarrow Colliery fired at the furnace, but an explosion was prevented. . . The pit was not at work, but there was a number of people down . . . wastemen and other people . . . the furnacemen came running out and informed them that the west pit furnace had fired. But it is frequently the case, under such circumstances, that before the explosion takes place there is a kind of libration in the ignited current, the flame not extending very far back from the furnace; it goes backwards and forwards a few times before the explosion takes place. This was the case at Jarrow, when Alexander Hall, the underviewer, with the utmost presence of mind and dexterity, ran and at once threw open the main doors in the rear of the burning current, by which the whole body of the fresh air was thrown in behind the fire, and instantly cut it off from the explosive current."

On 18th April, 1876, an explosion of fire-damp took place at the furnace of Seghill Colliery, Northumberland, burning the furnaceman, who died nine days afterwards. The gas in this case probably entered the ventilating current in the return from some drowned workings, out of which the water was being pumped at the time. The damage done to the mine was trifling.

With the exception of these three examples, the writers know of no case in the North of England of an explosion of fire-damp at a ventilating furnace.

Assuming, however, as was the opinion of some, that the five Durham explosions described, as well as numerous other large explosions, were caused by the ignition of large outbursts of gas, then, as the probability of such outbursts taking place is greatest at the working face, where new ground is being mined, and greater in the return air ways and passages open to them (as affording a large area available for a discharge of gas), than in the single roads constituting the intakes, and as the result, in the first two cases, would be the fouling of the return air ways, extensive explosions in the return air ways, due to the ignition of fire-damp at the furnace, should be of frequent occurrence at fiery collieries where the return air passes over the furnace, which is not the case.

So far as can be gathered, the return air roads of a mine in the North of England have never been the field of a large explosion.

The explosion at Seaham Colliery, in 1871, was confined to and extended along a haulage road and intake for about 2,300 yards. Stables by the side of the road, 2,200 yards from the shaft, were set on fire, but the explosion did not extend far beyond them. The explosion was simultaneous with the firing of a shot in stone by the side of the intake air way, 20 yards from where the shot was fired in the explosion described in 1880. Two stonemen were engaged there with naked lights, and 79,000 cubic feet of air per minute passed along the road. After lighting a shot the stonemen went in each direction from it. The explosion killed all the workmen between the shot and the face, the majority by after-damp. The stoneman who had retired from the shot against the air current was burnt, but survived, and stated that the explosion of the shot and the mine were simultaneous. The explosion was attributed to a sudden outburst of gas, ignited near the supposed point of issue, which was on the main intake, 1,700 yards from the out-bye or shaft limit of the explosion, and about 600 yards from its in-bye limit.

The explosion at Springwell Colliery, in 1869, had not extended from the face. The evidence of flame appears to have been abundant.

The explosion at Pelton Colliery, in 1866, occurred at the only colliery in the list ventilated by a fan. At all the other collieries a furnace, or, in cases in earlier times, natural ventilation was relied upon. The Busty Seam at Pelton Colliery resembles the same seam at West Stanley, and is very dusty. Flame appeared to have extended over all the open passages on the south side of the shafts, and abundant deposits of coked dust were observed. In a paper in Vol. V. of the "Transactions of the Chesterfield and Derbyshire Institute of Mining, Civil, and Mechanical Engineers," this explosion is described by Messrs. D. P. Morrison and A. Friere-Marreco. It appears from this paper, that a hewer was found with his safety lamp, in a passage, at right angles to and some yards from his place of work. All the other workmen appeared to have been killed at their place of work. It was suggested that this hewer had observed gas on his lamp, and had been retreating when flame passed the gauze. A small accumulation of gas had been observed in a passage some distance from him and not then in connection with the current of air, but which had, by excavation on the day of the accident, been so connected. This gas had not, however, been looked upon as a source of special danger. It appeared that the hewers were permitted to fire their own shots, and it is possible that this man had retired to the point where he was found after lighting a shot.

The explosion at Seghill Colliery, in 1864, and at Burradon Colliery, in 1860, occurred in districts adjoining. The Northumberland steam coal is, as a rule, not a dusty coal, and the roads are usually free from any dangerous deposits of coal dust; and no great explosions, with the exception of these two, have ever taken place in the steam coal pits. The workings and roadways were dry and dusty both at Seghill and Burradon in the district of explosion, and after the explosions coked coal dust was observed in both cases. At Burradon Colliery, there was evidence of a considerable amount of gas at the face, and a gas explosion appeared to have taken place about a quarter of an hour before the larger explosion. A number of men, alarmed by the first explosion, were retreating to the shafts when a second explosion took place, and this probably spread as a dust explosion. At Seghill Colliery, the disturbance produced by the explosion was greatest on the intake and haulage road.

The evidence appeared to show that Walker Colliery, previous to the explosion in 1862, was well ventilated, and no unusual source of danger was known. A shot had been fired in stone, near the floor of a return air road adjacent to the working face. An official, who was at the colliery at the time of the explosion, stated to one of the writers that the explosion of the shot and the mine had been simultaneous, and that the shot had blown out.

The Hetton explosion, in 1860, was ascribed to gas distilled from coal, and collecting in a flue from an underground boiler fire, and it was said that the damage done was due to the ignition of this assumed collection of gas. The amount of gas possible would appear to have been altogether too small to account for the extent of disturbance. The leading features of this explosion closely resemble those of the collieries described. The downcast shaft was damaged for 40 yards above the plane of the explosion. Stables near it were set on fire. The force of the explosion was confined to the intake and haulage roads for long distances. Those of the victims exposed to the violence or flame of the explosion were all found at their places of work. The return air roads were unaffected. Four stonemen were engaged, on the night of the explosion, in forming refuge holes by blasting in a portion of the engine plane, in stone; they were using, as lights, large oil lamps, said to be the only light that would live in the large current of air which passed their place of work.

At Felling Colliery, in 1847, an explosion occurred and was simultaneous with the firing of a shot in stone by the side of an intake and haulage road driven in stone. One of the stonemen engaged at the point survived, and he stated he was using an open light, and had retired from a shot after lighting it, and while waiting for its explosion, the pit exploded. This explosion, like that at Hetton, was attributed to an explosion of gas distilled from coal and collected in an underground flue.

The explosion at Hebburn Colliery, in 1852, was said to be due to a trapper neglecting a door. This reason is given, in several other explosions, as a contributory cause, but so far as can be gathered, in this, as well as in other explosions referred to the same cause, there was no evidence whatever to show that the door had been left open. The doors in all cases having been blown down and destroyed by the explosions.

The explosion at Jarrow Colliery, in 1845, was reported on for the Government by Dr. Lyon Playfair. Facts stated in this report show that this explosion was similar in its leading features to the explosions at the collieries described.

The explosion at Haswell Colliery, in 1844, was reported on for the Government by Messrs. Lyell and Faraday. They refer to the influence of coal dust, but do not appear to have looked upon it otherwise than as assisting, or intensifying the explosion of fire-damp and air.

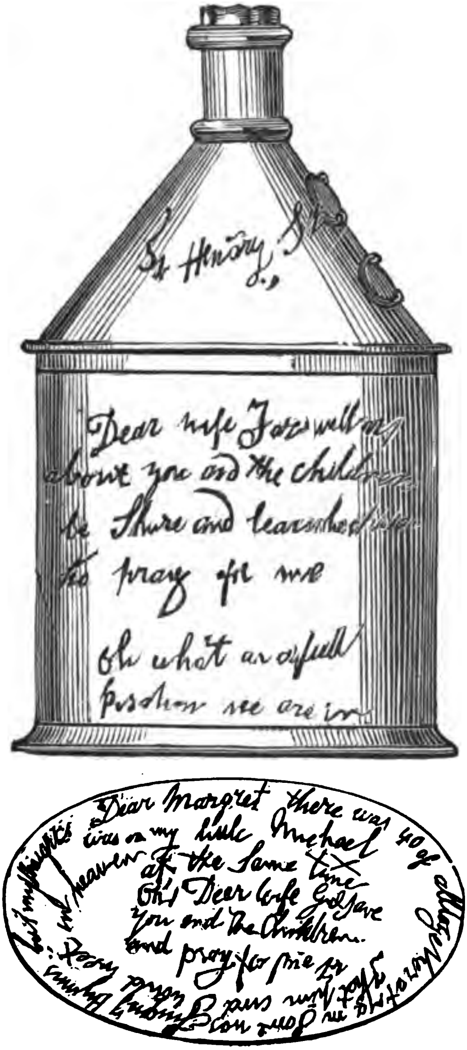
The explosion at Wallsend Colliery, in 1835, has been ably described by John Buddle, the leading mining engineer of his day in the North of England, and a close observer. His account of this explosion, published in the "Transactions of the Natural History Society of Northumberland Durham, and Newcastle-on-Tyne," Vol. II., presents a striking similarity to those described by the writers, and his remarks as to the point of origin are quoted :—"William Thompson with William Johnson were employed in blasting down the roof stone on the West drift leading to the A Pit, to make sufficient height for a branch of rolleyway to be laid. . . The main current of the air course . . . passed up this West drift to the B Pit burning furnace, being sufficiently pure for naked lights. Consequently the people were not restrained from the use of candles in blowing down the roof-stone . . . A pair of man-doors in the stenting K, which were placed there for the convenience of the wastemen. These doors are 40 yards to the east from the place where those men were at work blasting down the stone . . . William Thompson's body was found lying just at the entrance of the stenting K, and the bottom or cistern of his Davy lamp was lying uninjured 2 yards from the end of the stenting close to where the first door stood. The gauze cylinder was found hanging on a nail near to the place where he had been working. The body was dreadfully burnt; while the body of William Johnson was lying about a couple of yards to the east of it, nearer to the pit in a creeping attitude, but neither burnt nor exhibiting marks of any sort of violence. He had evidently died from suffocation without much suffering, as his Davy lamp was found in his hand. . . . It is a common practice with colliers, when working stonework, as in this case, to make use of the recess formed by a stopping or a pair of doors . . . as a closet for their clothes, tools, and provisions . . . but whether Thompson had approached the fatal spot for this purpose, or had been led there for a private occasion, or other object, must for ever remain unknown. Nothing could be more clear than that this was the point of ignition."

The explosion at Townley Colliery, in 1826, occurred in a part of the Durham coal-field free from any large explosion except this. One of the writers had an opportunity of examining workings, partly in those in which the explosion took place, and partly adjoining. He found the district to be dry and the coal produced much dust, and on roads in use there was coal dust to an extent exceptional in the collieries in the neighbourhood.

NOTE A.

The following extract from the *Durham Chronicle*, of 8th October, 1880, describes one of the records found up the West incline in the Maudlin Seam :—

Much public interest has been felt about the touching messages found recorded by some of the victims of the explosion. One of these is reproduced in the following fac-simile drawing of the tin bottle, on which the miner, Michael Smith, scratched with the point of a rusty brattice nail the farewell letter to his wife, the size being reduced one-half :—



St Henry S.

Dear wife Farewell m
about you and the child
be Shure and learn the
to pray for me
Oh what an awfull
position we are in

Dear Margret there was 40 of altogether at 7 o[illegible] some was singing hymns but my thoughts was on my little Michael [illegible] in heaven at the same time
Oh! Deer wife God save
you and the children
and pray for me

It is necessary to explain that the address of Smith, which appears in heavier and more distinct writing on the upper portion of the flask, had been marked there for some time, and grown rusted. On the other side, which was greatly battered and bent, appeared, also in old writing, the man's name in full, with the date distinctly and firmly traced, "Anno 1880," this being also bitten in with rust. Under this inscription he had scratched the words "Look at the bottom;" his obvious reason being that the plain flat surface afforded a better ground for writing upon. When he had filled up this oval space, he continued the letter, as seen above, on the less battered side of the flask; and it would appear that the last words, "Oh what an awful position we are in," were added sometime afterwards, probably not long before his death. They are less firm than the rest of the writing; but every line seems to indicate the perfect self-possession of the poor fellow, and his heroic calmness in presence of a cruel death. Michael Smith, who was thirty-seven years of age at the time of this fatality, was the son of a schoolmaster in this county. He was evidently a good writer, and could also play the violin fairly well. Two of his children are living, the "little Michael," so touchingly named in the letter, having died on the day of the explosion. The poor widow was nursing her sick child when she heard the dull thud that bore the message of a more terrible deprivation. In dying, Michael Smith clasped this bottle so closely under his right arm that it escaped the notice of the explorers, even when the body had been brought to the surface; and it was the afflicted wife and mother who herself made the discovery of this sad relic, which she now treasures with the greatest affection. No more pathetic memorial of human love and faith overcoming mortal anguish could be preserved.

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